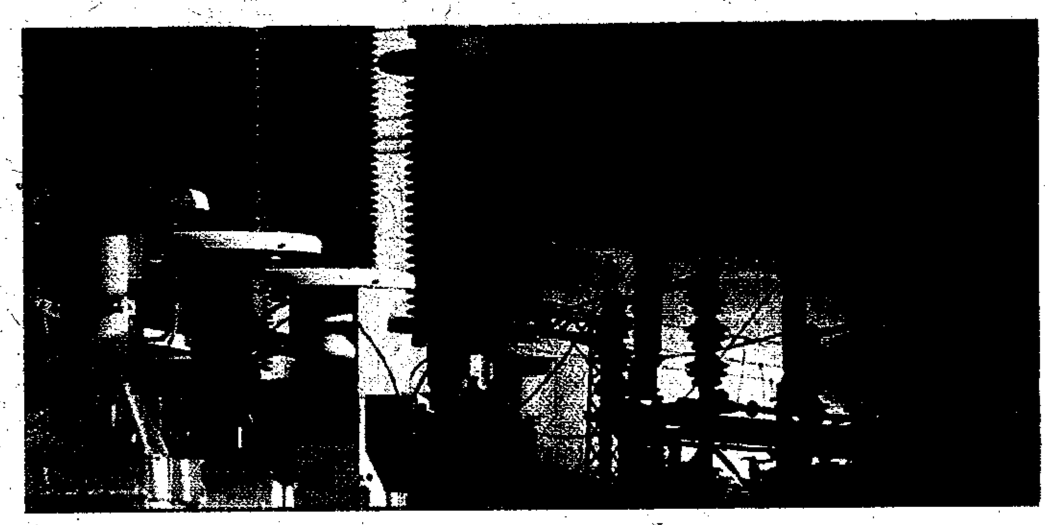
ECO PN-ACQ-192

Energy Conservation and Commercialization Project

A Program of USAID, Ministry of Power & ICICI



MARKET ASSESSMENT REPORT

JANUARY 2001

Activity 4: Efficient Technology Promotion Milestone 4B: Market Assessment Report

Principal Investigators:

Kapil Thukral, Nexant, Delhi
Brian Wood, Nexant, San Francisco
Anil Sachdeva, Consulting Engineers Company, Delhi

USAID Contract Number: LAG-I-809-98-00006-00

23865-809.0015

TABLE OF CONTENTS

Acronyms and Abbreviations

CCP	Combined cycle plant
COP	Coefficient of performance
CT	Current transformer
CFL	Compact fluorescent lamp
EE	Energy efficient
EM	Electro-magnetic
ESCO	Energy service company
GHG	Greenhouse gas
GLS	General lighting system
GOI	Government of India
GWh	Giga watt hour
HSD	High speed diesel
HT	High tension
IPP	Independent power producers
kW	Kilo watt
kWh	Kilo watt hour
LRMC	Long run marginal cost
LSFO	Low sulphur furnace oil
LT	Low tension
MW	Mega watt
SERC	State electricity regulatory commission

Preface

This report is a part of the deliverable for Milestone 4B, to submit market assessment on end-use technologies, to determine which technologies have the greatest potential for reducing energy consumption and GHG emissions in India. The Assessment Report has covered the sales patterns by size, efficiency, customer and other relevant parameters.

The ECO project is being implemented by Bechtel National Inc. (Nexant Inc.) under a USAID contract, LAG-I-00-98-0000. This contract has been issued by the USAID Mission, in New Delhi as a part of the IQC (Indefinite Quantity Contract) currently in place through USAID's Global Bureau. The project contract was signed on February 29, 2000, and continues through December 2003.

Background

The Government of India (GOI) and the US Agency for International Development (USAID) signed a joint project agreement on 28 January 2000 that calls for the implementation of the Energy Conservation and Commercialization (ECO) project. The ECO project will target the reduction of greenhouse gas emissions per unit of electricity generated and consumed in India.

India is currently the world's sixth largest and second fastest growing source of global greenhouse gases. This new initiative is in furtherance of the Joint Statement on Cooperation in Energy and Related Environmental Aspects signed in October 1999 between USA and India.

ECO aims to promote widespread commercialization of energy efficiency technologies and services in India, thereby contributing to the reduction in growth of GHG emissions. Assistance is provided for developing a market oriented policy environment for commercialization of energy conservation, and enhancing the capabilities of private and financial sectors for deploying market-based mechanisms for energy efficiency investments. The ECO project supports USAID's Climate Change Strategy, and will contribute to USAID / India's Strategic Objective for increased environmental protection in energy, industries and cities.

ECO will further facilitate the commercialization of energy services and technologies through a two-pronged strategy:

- Energy efficient market development and financing (Markets Component); and
- Energy efficiency policy and institutional reforms (Policy Component).

The Markets Component includes the following major Activities:

- Activity 1: Technical and project structuring services for sponsors
- Activity 2: Development of financial incentives for credit enhancement / risk mitigation
- Activity 3: Support to energy efficiency services industry
- Activity 4: Efficient technology promotion
- Activity 5: Market conditioning and promotion
- Activity 6: Non-sugar cogeneration market development

The Policy Component will cover policy, regulatory and institutional reform issues at the central and state levels, and will include the following major Activities:

- Activity 7: Energy efficiency policy and institutional support
- Activity 8: Energy efficiency standards for labeling for consumer appliances
- Activity 9: Energy efficiency improvements in Government facilities and private buildings
- Activity 10: Energy efficiency through regulatory reform and restructuring
- Activity 11: Electric utility DSM / energy efficiency capacity building
- Activity 12: Development of State energy efficiency financing schemes
- Activity 13: DSM / energy efficiency within privatized distribution utilities

Technical assistance (TA) and training will be provided to various Government agencies to help them create a market-oriented policy environment conducive to investment in efficiency. TA and training will be provided to the private and financial sector to design and implement energy conservation projects. The Ministry of Power (and the Bureau of Energy Efficiency, expected to be created after the proposed Energy Conservation Bill is enacted) will be the partner agency for the ECO project. State-level activities under the Policy Component will be coordinated with the State Regulatory Commissions and State Electricity Boards (or its functionally unbundled entities) of the focus state(s).

Executive Summary

Two of the ECO project's principal activities are efficient technology promotion and market conditioning. Much of the work in both these activities will involve tasks to develop the markets for two promising energy efficient (EE) products, which have yet to be selected.

This study is preparatory to product selection. It identifies the technical potential for energy savings throughout India for each of nine products, and consumer buying patterns that are relevant toward developing promotion and market conditioning programs that will stimulate the market penetration of EE products.

The seven products and their technical potential for energy savings are as follows:

Energy Efficient Product	*Technical Potential (GWh/yr)*
Compact Fluorescent Lamp (CFL)	13,636
T8 Fluorescent Lamp	1,150
EE Magnetic Ballast	2,130
Electronic Ballast	3,766
T5 Fluorescent Lamp with Ballast	7,208
EE Refrigerator	9,077
EE Room Air Conditioner	1,687
EE Ceiling Fans	4,089
EE Motor	
-under standard replacement	7,382
- in place of rewinding	13,241

The table shows technical potential, which is the assessment of potential energy savings without consideration for economic or market barriers that affect how much of the potential savings may be realized. In most cases these barriers are substantial, though not insurmountable. They are assessed in a companion report under ECO Milestone 5A.

Market characteristics and consumer buying patterns are relevant both to the assessment of market barriers and to the design of effective programs to reduce the barriers. The most important findings of this analysis include the following:

- *Compact Fluorescent Lamps:* the segments with the majority of untapped potential are low- to middle-income households that are unable to afford these relatively high-cost lamps. Financial assistance would be required to penetrate this market and realize the large savings potential.

- *T8 Fluorescent Lamps:* barriers to penetration of this product are due primarily to consumer and distributor perceptions of poor quality that may be dispelled through independent product testing and promotion.

- *EE Magnetic and Electronic Ballasts:* the gray sector is the predominant producer of standard ballasts, and its protected status and very low cost restricts growth in sales of more efficient products, except among the minority of consumers who require a high quality product.

- *T5 Fluorescent Lamps with Integral Electronic Ballasts:* this newly introduced product offers substantial energy savings and product quality improvements, but its high price is expected to restrict severely its marketability, and claims of extended service life need to be verified.

- *EE Refrigerators:* efficiency levels have raised such that much of the savings potential may be realized through attrition of old refrigerators, but the market still may not sufficiently address raising the efficiency level of the "no-frills" standard, 165-liter model that is purchased by the majority of middle- and lower-income households.

- *EE Room Air Conditioning Units:* for this product, the primary residential consumer market is relatively indifferent to energy efficiency in comparison to other features; energy efficiency must be combined in a package with other features, perhaps through a mandatory standard.

- *EE Ceiling Fans:* this product is not yet available in the Indian market, despite pervasive use of ceiling fans in all sectors. The barriers are substantial and would require extensive market intervention efforts to overcome.

- *EE Motors:* high penetration of EE motors will require the most extensive level of market intervention, incorporating promotion, technical assistance, and financial assistance aimed principally to recruit motor distributors as allies in increasing the availability of EE motor supply and to stimulate awareness and consumer demand sufficiently to lead OEMs (original equipment manufacturers) to incorporate EE motors in their products.

Section 1 Introduction and Overview

This report is the result of one of the introductory technical assistance tasks associated with the market conditioning and efficient technology promotion activities of the ECO project. The study's objective is to evaluate promising products and related consumer segments toward further focus and development of program designs in later stages of the project.

This Milestone 4B study focuses on an assessment of technical energy efficiency potential of the subject products and characterization of their respective potential markets in terms of consumer segments, buying patterns, and potential interventions in the market that may help to stimulate the penetration of EE products. This 4B study is closely linked to a parallel task under Milestone 5B, which assesses the market EE potential for the same products considered here.

The EE products considered in this report were defined by a preceding specification of target energy end uses and consumer segments. The products were selected on the basis of those with the highest total technical potential for energy savings within the defined segments, which included the residential, commercial, industrial, and institutional segments and their use of the following technology areas:

- Lighting devices
- Lighting accessories
- Refrigeration
- HVAC
- Motors
- Water heating

This report is organized in four sections following this introduction. Section 2 describes the analytical methodology used to evaluate technical energy efficiency potential. Section 3 describes the analysis of the number of the respective energy-using equipment in stock today and associated energy consumption. This step was necessary to resolve conflicts among some data sources and to assure that assumptions, required to estimate technical EE potential, are internally consistent. Section 4 presents the technical potential analysis itself, noting the principal data sources and assumptions of the study team. Section 5 presents the analysis of market characteristics, consumer buying patterns and steps required to overcome market barriers for each of the EE product categories.

Section 2 Methodology of the Technical EE Potential Assessment

The study team has estimated technical EE potential in a two-step process. The first step assesses the current level of energy consumption associated with each consumer technology for which there is a substitutable EE option, disaggregated by consumer sector. This analysis may be considered an accounting and reconciliation of energy sales with estimates of appliance stocks and their usage patterns in the marketplace. This step establishes the baseline energy consumption. In the second step, energy efficiency improvements associated with EE equipment options are compared to assess potential energy savings.

2.1. Energy Consumption and Equipment Stock Accounting

This study was designed to rely principally upon secondary data sources, and the approach to estimate energy consumption associated with the relevant technologies and equipment categories was determined partly by data limitations. Market research in India has been extremely limited with respect to ownership and usage patterns of major energy-using products, characteristics of the appliance stock, sectoral energy consumption and market segmentation, consumer preferences, etc. The available data sources are generally based upon analysis of very limited and geographically isolated samples, which are assumed to be representative of the diverse Indian market. For several sources, neither analytical methodologies nor assumptions are explicit, and it is not possible to differentiate the reported data in terms of assumptions, derived values, and observations based upon research. Several sources are also old, and there are well-founded indications that sales and usage patterns have changed. Nevertheless, there are sufficient data points to develop a reasonable characterization of energy use, to enable an internally consistent assessment of technical EE potential. This was the objective of the energy consumption and equipment stock accounting exercise.

The principal data sources include the following:

- 1999/2000 estimates of product sales and market segmentation, obtained principally through personal communications with senior manufacturer representatives during the period November 2000 to January 2001.
- Statistical data relating to Indian equipment production and the market stock from a variety of sources (ELCOMA, IEEMA, CSO, Kirloskar Consultants report (1997), etc.)
- Electricity consumption by sector in 1996/1997 and 1999/2000 (CEA)
- Estimates of energy end-use consumption, usage patterns, and efficiency levels of the existing equipment stock by technology, principally cited in two reports:
    - o "Efficient Electric End-Use Devices: The Indian Market," RMA (1996) (RMA/IND-EMCAT-BFR-02-F)
    - o "Opportunities for Improving End-Use Electricity Efficiency in India," ACEEE (1991), with updates by V. Kothari provided in an October 2000 presentation associated with USAID/MMEE project findings.

- Comparative data on relative sectoral energy sales and end-use shares from the USA, Canada, Thailand, Egypt, and Brazil, used parsimoniously as reference points.

In developing the analysis of segmented energy consumption, it was not uncommon to find the implications of different data sources to be contradictory. The study team used a combination of logic, judgment, and qualitative knowledge about the Indian market to resolve such conflicts and reconcile the available data.

While there is a considerable degree of uncertainty in the estimates, which passes through to the estimates of technical EE potential, the results remain sufficiently robust to select the two to three most promising product/technology options, in terms of their EE potential, for the purposes of market promotion and conditioning under Activities 4 and 5 of the ECO project. The analysis also supports the identification of target market segments and key market barriers associated with each product/technology.

2.2. Assessment of Technical EE Potential

For each EE option, technical potential was estimated by comparing the energy use of the best available technology in the market today, in terms of energy efficiency, with that of the typical standard product being purchased on the market. The resulting difference in unit energy requirement was applied to the assumptions about the current stock and typical use of the product, developed in the preceding stock accounting and energy consumption step, to assess potential energy savings. This represents technical EE potential, without taking into account the economics of the EE option relative to the current, prevailing practice of purchasing the non-energy efficient, standard product.

This approach evaluates the impact of altering consumer purchase behavior to use the EE product rather than the inefficient product when it comes time to purchase the consumer's existing unit. This is approach is appropriate in evaluating consumable products, such as lamps, for which replacement is frequent and the existing stock in use is consistent with the efficiency level of products available in the market.

Consumer durables, meaning long-lasting products, present a different situation in that older units may be considerably less energy efficient than even the least efficient products available on the market today, because the overall efficiency level of supplier product lines has improved over time. This is particularly true of refrigerators and room air conditioners, which may continue to perform satisfactorily after 15 years of service. For durable products, the technical potential assessment evaluates the energy savings impact of replacing the appliance stock, which is quite inefficient compared to products available on today's market, with the most efficient available product. However, such efficiency gains may be expected to take years to materialize, unless consumers can be persuaded to replace their existing units before the end of their useful lifetime. If not, then considerable energy savings will be realized even as replacement occurs naturally, and even if consumers do not choose the most efficient units available on the market. These savings may be considered a subset of the reported technical potential assessment.

Motors present a further special case. When motors fail, in 90 percent of the cases they are sent for rewinding rather than replaced with a new motor. Typical rewinding practices cause substantial degradation of motor efficiency over the motor's useful lifetime. US tests indicate that the degree of degradation depends upon rewinding methods, but regardless of method the degradation is generally less for EE motors than for standard motors.

The technical potential assessment for motors considers two cases. One case evaluates the substitution of an EE motor for a standard motor when the existing motor is to be replaced. This would occur in 10 percent of the motor failure cases, and total replacement of the existing motor stock would take years because most motors would be rewound repeatedly until they reach the point of irreparable damage. The second case evaluates replacement of existing motors at the time of failure, meaning that they would be replaced by an EE motor rather than being rewound. In this case, the incremental efficiency gain is greater, because the EE motor is compared to a motor that is considered to have suffered efficiency degradation due to rewinding compared to its efficiency rating when it was purchased.

In all the technical potential assessments, the evaluation considers replacement of the existing equipment stock without considering the purchase of new appliances or equipment that will be associated economic growth in the future. Over time, the market for each product/appliance increases as a function of industrial, commercial and population growth, and in response to evolving trends in consumer preferences and living standards. Technical EE potential will also increase in parallel to these changes. However, evaluation of market growth was considered beyond the scope of this analysis.

Section 3 Energy Consumption and Equipment Stock Accounting

The energy consumption and equipment stock accounting analysis was differentiated into four areas according to the principal opportunities for energy savings indicated by previous studies, and specified in the scope of work defined for this study. The four areas include lighting, refrigeration, air conditioning, and motors. They are each presented below.

3.1 Lighting

The assessment of lighting unit stock, characteristics, and energy consumption are differentiated into four technology categories:

- *GLS,* or General Lighting Service, which are incandescent lamps
- *FTL,* which are straight-tube, fluorescent lamps
- *CFL,* or compact fluorescent lamps
- *HID,* or high intensity discharge lamps, which include primarily mercury vapor and high pressure sodium lamps, but also include metal halide and low pressure sodium technologies

For each major consumer sector, sales and stock levels are presented in Table 3.1; Table 3.2 shows the corresponding energy consumption. The consumer sectors include residential, commercial, industrial, and other (which comprises public lighting, public water works, and miscellaneous non-industrial). These sectors are used throughout the technical potential analysis.

Table 3.1 Lighting Units

Sector	*Unit Type*	*Light Points (millions)*	*Share of Light Points (%)*	*Lamp Lifetime (Hours)*	*Annual Lamp Sales (millions)*	*Sector Share of Sales (%)*
Residential	GLS	272	91%	435	655	87%
	FTL	76	40%	3000	36	23%
	CFL	5	19%	5000	2	10%
	HID	0				
	Subtotal	353				
Commercial	GLS	18	6%	667	49	6%
	FTL	75	39%	3000	75	48%
	CFL	18	63%	5000	11	70%
	HID	0				
	Subtotal	110				
Industrial	GLS	6	2%	667	24	3%
	FTL	27	14%	3000	32	20%
	CFL	5	18%	5000	3	20%
	HID	6	62%	16000	1	62%
	Subtotal	44				
Other	GLS	5	2%	667	22	3%
	FTL	12	6%	3000	16	10%
	CFL	0	0%	5000	0	0%
	HID	3	38%	16000	1	38%
	Subtotal	20				
Total	GLS	300			750	
	FTL	190			158	
	CFL	28			15	
	HID	9			2	

Table 3.2 Lighting Energy Consumption

Sector	Unit Type	# of lamps (millions)	Ave Rating (W)	Utilization (%)	Operation (Hrs/yr)	Energy Use (GWh/yr)	Sector End-Use Share (%)
Residential	GLS	272	70	75%	1400	19,955	27%
	FTL	76	55	90%	1400	5,272	7%
	CFL	5	23	90%	1400	158	0%
	HID						
	Subtotal					25,385	34%
Commercial	GLS	18	70	60%	3000	2,268	9%
	FTL	75	55	60%	3000	7,421	31%
	CFL	18	23	90%	3000	1,103	5%
	HID						
	Subtotal					10,791	45%
Industrial	GLS	6	70	90%	3000	1,134	1%
	FTL	27	55	90%	3500	4,687	4%
	CFL	5	23	90%	3000	315	0%
	HID	6	200	90%	4000	4,075	3%
	Subtotal					10,211	9%
Other	GLS	5	70	83%	4000	1,040	6%
	FTL	12	55	83%	4000	2,148	13%
	CFL	0	23	83%	4000	0	0%
	HID	3	200	83%	4000	2,297	14%
	Subtotal					5,484	34%
Total	GLS	300				24,397	47%
	FTL	190				19,528	38%
	CFL	28				1,575	3%
	HID	9				6,372	12%
						51,872	100%

Energy consumption for lighting was estimated using the ACEEE study as a starting point for assumptions, with adjustments according to recent data on the distribution of lamps. In some cases, recent information from suppliers contradicted the ACEEE assumptions. For example, the lighting industry reports that 40 percent of FTL light points are attributed to the residential sector, whereas the ACEEE study team assumed negligible FTL penetration among households, with no explicit basis reported for that specific assumption. The ECO study team adopted the lighting industry assumption, which had the effect of increasing the total implicit lighting energy consumption in that sector compared to the ACEEE findings.

Specific assumptions and conclusions associated with Tables 3.1 and 3.2 are summarized as follows:

- *Residential sector.* Lighting energy use was based initially upon a target 28 percent of total sector consumption, from the MMEE analysis, representing an update to the ACEEE study. The majority of this share was associated with GLS lamps (27 percent out of the total 28 percent). However, due to supplier indications of greater FTL use by households than assumed in ACEEE and

MMEE, the total lighting end-use share was assessed at 34 percent for the residential sector. Input assumptions for calculating energy use include:

- *Number of lamps.* Based upon assessed light points (see below for each unit type).
- *Average rating.* For GLS and FTL types, the lamp size represents the weighted average of sales reported by manufacturers. For CFL, the size represents the appropriate replacement for the given average rating of GLS lamps.
- *Utilization.* Assumed to be 75 percent for the sector, consistent with ACEEE. CFL lamps assumed to replace high-usage GLS lamps only, and were assessed a relatively high utilization at 90 percent.
- *Operation.* All lamps assumed at 1,400 hours per year, consistent with the reported value from ACEEE for GLS operation by households.

- *Commercial sector.* Although assessed in MMEE/ACEEE to have a lighting end-use share of 50 percent, this analysis revises the share downward to 45 percent. This follows attribution of a larger FTL share to the residential sector. Assumptions for utilization and operation are consistent with the ACEEE study.

- *Industrial sector.* The lighting end-use share is unchanged from the ACEEE study finding, at 9 percent. The relative shares by lighting type have changed, as HID lamps have gained relative to the former FTL share. Assumptions for utilization, operation, and the average lamp size for HID sources are consistent with the ACEEE study.

- *Other sector.* The weighted average end-use share represented by this category is consistent with the ACEEE study at about 36 percent. HID lamps are also assumed to have gained share against FTL, consistent with overall HID sales growth. Assumptions for operation and utilization are consistent with the ACEEE study.

- *GLS lighting.* Based upon a range of estimates from manufacturers, total GLS lamp sales are about 750 million, including both branded products and the unorganized sector, and there are about 300 million GLS light points. The distribution of light points among consumer sectors was developed to be approximately consistent with target end-use shares.[1] Average lamp lifetime, used in relating annual lamp sales to total light points, is differentiated between the

[1] This approach implied a different distribution of light points among the consumer sectors than suggested by some manufacturers. Specifically, while suppliers estimate that about 70 percent of GLS points are associated with households, this analysis estimates a 90 percent share for that sector. The former distribution would imply much higher total lighting energy consumption in the non-residential sectors than assessed by the ACEEE study, and higher than would seem reasonable in comparison to experience of other countries. In addition, as the suppliers polled represent the organized sector, with a 2/3 GLS market share, it may be reasonable to assume a higher domestic share when the products from the unorganized sector are taken into account, particularly in consideration of rural areas which are served almost exclusively by the unorganized sector and which comprise primarily of domestic lighting consumers.

residential and all other sectors to reflect the greater market share of non-branded, inferior quality GLS products in the domestic sector, particularly in rural areas.

- *FTL lighting.* FTL sales in 1999/2000 were 158 million, and total light points were estimated on the basis of FTL lifetime and operating hours. The distribution of FTL light points follows from suppliers, who attribute 40 percent to the domestic sector. Distribution among the other sectors is consistent with target total energy end-use shares, with the majority share attributed to the commercial sector.

- *CFL lighting.* CFL sales in 1999/2000 were 14-16 million units. Total light points were estimated based upon an assumed rapid growth in sales in recent years, taking into account lamp lifetime and operation. The distribution among sectors is assumed, with the majority share attributed to the commercial sector as is generally observed.

- *HID lighting.* No data on HID sales was available from surveyed manufacturers. Total HID light points were estimated, based upon the number reported in ACEEE for 1989/1990 and escalated at the growth rate observed for GLS and FTL lamps for the 89/90 to 99/00 period. The distribution among sectors is consistent with the ACEEE study.

3.2 Refrigeration

Refrigeration as an end use includes industrial process refrigeration for chemicals production, cold storage and freezing in the food processing industry, refrigerator cases and cold storage used in the commercial sector, and refrigerators used in households and small-scale commercial shops and retail food service. Industrial refrigeration was not considered in this analysis, as EE opportunities are highly site-and design-specific. Domestic refrigerators represent a branded product with clearly defined EE improvement potential, based upon international experience. They are also estimated to represent the largest energy share for this end use, and are the focus of this analysis.

The estimates of refrigerator stock in the market and related energy consumption, summarized in Table 3.3, are based principally upon survey research reported in the 1996 EMCAT report, a referenced TERI report, and data on the refrigeration stock prior to 1990 noted in the ACEEE study. Principal assumptions include the following:

- *Target residential end-use share.* The EMCAT report estimated that refrigerators accounted for 15 percent of residential electricity consumption in 1995. This was escalated to 2000 based upon the relative growth rate of 10.4 percent for residential electricity demand and TERI's projection of 16 percent annual growth in refrigerator sales from 1995 to 2000. The relative growth rates implied that refrigerators would represent 19 percent of residential demand in 2000.

- *Appliance stock.* NCAER reported in 1998 that 23 percent of urban households have at least one refrigerator, and that rural households account for 24 percent of new refrigerator purchases. EMCAT reported total refrigerator sales of 1.4 million in 1995, annual sales growth of 16 percent projected through 2000, and that 90 percent of sales are for new purchases. The implicit projected appliance stock in 2000 was 23.9 million units (also assuming that the commercial sector represents 5 percent of sales for domestic-sized units).

- *Daily energy consumption.* This value is implied by the target residential energy use for refrigerators and the appliance stock. In 1995, EMCAT estimated that domestic refrigerator energy consumption was 15 percent of overall domestic electricity. Trends in the growth of refrigerator sales and domestic electricity sales suggest that this share would grow to 19 percent by 2001. This implies that the average daily energy consumption is about 1.7 kwh/day, which compares well to market data. In 2001, rated energy consumption for units available on the market range from 1.0 to 2.0 kwh/day for the typical 165-liter domestic model. In 1995, the range was 1.2 – 3.1 kwh/day as reported in by the EMCAT study. Units typical of the commercial sector were assumed to be larger, with average consumption of 1.9 kwh/day.

- *Sector sales distribution.* The residential sector is assumed to account for 95 percent of the refrigerator market, and the remaining 5 percent is attributed to the commercial sector.

Table 3.3 Refrigerator Stock and Energy Use

Sector	*Annual Sales (millions)*	*Sector Share of Sales (%)*	*Appliance Stock (millions)*	*Utilization (%)*	*Daily Energy Use (kWh/day)*	*Energy Use (GWh/yr)*	*Implied Sector End-Use Share (%)*
Residential	2.2	95%	22.7	100%	1.7	14,113	19%
Commercial	0.1	5%	1.2	100%	1.9	821	3%
Total	2.3		23.9			14,934	

3.3 HVAC

Heating, ventilating and air conditioning (HVAC) is a pervasive end-use across consumer sectors, but tends to be concentrated in the residential, commercial, and institutional sectors. In India, ventilation by small electric table or ceiling fans dominates HVAC energy consumption. Heating is relevant only to North India, and its contribution to national energy consumption is slight, although there are important regional power demand considerations not addressed in this study. Air conditioning is the remaining element of HVAC, representing about 3-5 percent of non-agricultural electricity consumption.

Air conditioning is accomplished by central building systems using chillers and by unit air conditioners such as split systems and unitary window models. This analysis focuses on unitary models, which dominate the market and represent the majority of air conditioning energy use. Central systems and chillers represent important EE targets for building operators, but are not relatively pervasive in Indian buildings. Suppliers estimate that there are fewer than 1,000 large chillers (for building cooling) in the marketplace, and their estimated total cooling capacity is less than 20 percent of that represented by unitary systems.

The estimates of the stock of room air conditioners in the market and related energy consumption, summarized in Table 3.4, are based upon survey research reported in the 1996 EMCAT report, the ACEEE study, and communication with Indian suppliers.[2] Principal assumptions include the following:

- *Appliance stock.* Both the EMCAT and ACEEE studies indicate annual sales levels in the range of 100,000 units, with a gradual upward trend. The total stock was estimated at 15 years of sales.
- *Sales distribution by sector.* Market research in 1997/1998 indicated that households represent 50 percent of the room air conditioner market. The balance is attributed to the commercial sector, as the industrial and institutional shares are assumed to be negligible.
- *Average rating.* The typical unit size in both residential and commercial markets is 1.5 tons. This corresponds to a rating 2.5 kW as typical, with a relatively wide variation including more efficient units available today (COP 9-10) and inefficient models typical of older units (COP 6.7-8).
- *Full load operation.* The EMCAT report cites EMC test results that show average full load operating hours for 1.5 ton units at 1,600 hours per year. A higher figure is assumed for the commercial sector at 2,000 hours, due to longer hours of use compared to households, which generally use air conditioning only during the evening.

The resulting end-use shares for air conditioning are 4 percent of residential energy consumption and 17 percent of commercial energy consumption. The residential energy end-use share is consistent with the ACEEE report. The commercial energy end-use share represents a significant portion of overall commercial HVAC use (about 40 percent of total commercial electricity consumption), the balance being attributed to ventilation.

[2] A further update on current sales levels is pending information to be received subsequent to the submission of this draft report. This information relates to the inclusion of unorganized sector sales in the referenced data.

Table 3.4 Air Conditioner Stock and Energy Use

Sector	Annual Sales (millions)	Sector Share of Sales (%)	Appliance Stock (millions)	Average Rating (W)	Full Load Operation (Hrs/Yr)	Energy Use (GWh/yr)	Implied Sector End-Use Share (%)
Residential	0.05	50%	0.8	2500	1600	3,261	4%
Commercial	0.05	50%	0.8	2500	2000	4,076	17%
Total	0.11		1.6			7,337	

Energy efficiency potential among electric fans has not received much attention in past assessments, with the exception of the ACEEE study. Considering the pervasive use of ceiling fans, this report updates the ACEEE assessment to reflect growth in consumer demand, and to provide a comparison to EE opportunities among other consumer products. Table 3.5 reports the estimated stock and energy consumption for ceiling fans only. The principal assumptions include the following:

- *Appliance stock.* In the residential sector, the stock estimate is based upon the assumption that urban households with electricity have 2 ceiling fans, and that rural households with electricity have 1.5 ceiling fans on average. These assumptions are unchanged from the 1991 ACEEE report.[3]

- *Distribution among consumer sectors.* No survey data was available concerning the population of ceiling fans among non-residential sectors, although they are known to be pervasive. The indicated appliance stocks by sector are intended to be illustrative, estimated from expected energy end use shares for HVAC in those sectors.

- *Average rating and utilization.* Ceiling fans typically have a rating of 70 watts. Many models have multiple speed control, although this is typically accomplished by a resistance type controller and does not save energy. Hence, fans are assumed to operate at 100% of load despite partial operation at low speeds.

- *Operation.* The operating period is assumed to be 2,500 hours per year, taken from the ACEEE report.[4]

[3] ACEEE, p201.
[4] ACEEE, p200.

Table 3.5 Ceiling Fan Stock and Energy Use

Sector	*Appliance Stock (millions)*	*Average Rating (W)*	*Utilization (%)*	*Operation (Hrs/Yr)*	*Energy Use (GWh/yr)*	*Implied Sector End-Use Share (%)*
Residential	133	70	100%	2500	23,253	31%
Commercial	7	70	100%	2500	1,195	5%
Industrial	7	70	100%	2500	1,195	1%
Institutional	9	70	100%	2500	1,618	25%
Total	156				27,261	

3.4 Electric Motors

Electric motors are the most pervasive electric energy end user and the dominant end use in the residential and industrial sectors. The focus in terms of technical EE potential is on energy efficient motors. The EE improvement potential for motors varies with motor size and type, and the stock is differentiated into relevant categories. In addition, the economic potential for EE motors varies by tariff category, necessitating the relevant differentiation of the motor stock and energy use at this level also.

Data limitations constrain the crossways desegregation of energy consumption by motor size category and consumer sector, requiring an iterative approach to testing assumptions against reported values for sectoral energy consumption and total installed capacity by motor size category. Tables 3.6 and 3.7 show the results of this analysis. The principal assumptions and sources are indicated below:

- *Sector and market segments.* The analysis captures seven market segments, as follows:
  - *Residential.* Motors are assumed to account for 59 percent of energy use, based upon the ACEEE study, representing primarily ventilation, air conditioning, and household appliances.
  - *Commercial.* Motors are assumed to account for 40 percent of energy use, after the 45 percent end use share for lighting and allowing 15 percent for miscellaneous plug loads, water heating, etc.
  - *Industrial.* Motors are assumed to account for 74 percent of energy use, based upon the ACEEE study. The industrial sector is further differentiated into three segments to allow differentiation in the analysis of economic potential for three major tariff categories. No data was available to divide the motor stock among these categories. Hence a best effort was made to make reasonable assumptions, which are described below under segment shares. The three industrial categories are:

- *Small/cottage industry*
- *Other low tension (LT) industry*
- *High tension (HT) industry,*

The HT segment was estimated to represent 75 percent of industrial motor energy consumption, following from assumptions on the distribution of motors by size (described further below). The remaining energy shares were divided among the other categories by assumption, assigning 15 percent to the Other LT segment and 10 percent to cottage industry.

- *Other.* Motors account for an approximate weighted average of 57 percent of this category, which includes public lighting (0 percent motors), public water works (100 percent motors), and miscellaneous non-industry (assumed 40 percent motors).

- *Motor rating and type.* Six categories were assessed, selected to correspond with the size categories reported in data on AC induction motor production over the past 10 years. The categories include the following:
  - *1-phase, 7.5 kW or less*[5]
  - *3-phase, 7.5 kW or less*
  - *3-phase, 9.3 – 15 kW*[6]
  - *3-phase, 18.5 – 30 kW*
  - *3-phase, 37 – 45 kW*
  - *3-phase, greater than 45 kW*

- *Installed capacity and segment shares.* The installed motor capacity in the market and distribution of capacity among motor size ranges and consumer sectors were developed through an iterative process on the basis of comparisons among several data sources, assumed total motor end use shares by sector (noted above), and the assumptions about operating characteristics. The principal assumptions involved in this process include the following:
  - *Single-phase motors.* All residential motor energy consumption was assumed to be single-phase motors. Total single-phase motor consumption was assumed to be 36 percent of overall motors energy use, based upon observed distributions by sector and comparison to US data, through an iterative process of testing assumptions. The distribution among non-residential categories was made on the basis of their total motors energy use.

[5] Essentially all single-phase motors were assumed to be in this size category.

[6] Note that the rating ranges are specified in terms of the discrete size levels of motors available on the market, covering all available motor sizes. For example, where the first category covers all motors rated 7.5 kW or less, the next category begins with motors rated at 9.3 kW because this is the next available motor size greater than 7.5 kW.

- *Three-phase motors in industry.* The size distribution of installed motor capacity in industry was based upon a TERI survey cited in the ACEEE report. Overall motors installed capacity was estimated by escalating the assessed capacity in 1990 at the growth rate of total industrial electricity consumption from 1990 to 2000. All three-phase motors in cottage industry were assumed to be less than 7.5 kW, and all motors rated greater than 45 kW were assigned to the HT segment. The remaining motor capacity was distributed among the LT and HT segments in accordance with their relative motor energy use and the overall industrial distribution of motor capacity by size.

- *Three-phase motors in commercial sector.* Essentially all motors were assigned to the smallest two size ranges, and consistent with the US motors distribution among these categories, two-thirds of three-phase motors were assigned to the small size category (7.5 kW and less) and the remainder assigned to the next largest category.

- *Three-phase motors in the other sector.* The public water works category was assumed to be comprised of primarily large motors, and the remaining energy consumption was distributed as in the commercial sector.

- *AC induction squirrel cage type share.* The share of motors represented by the AC induction squirrel cage type (for example, excluding DC, synchronous, and other motor types) was based upon data cited in the ACEEE study.

- *Average rated efficiency.* Rated motor efficiency was based upon discussions with manufacturers and their product information.
- *Average in-service efficiency derating.* The indicated assumptions correspond to efficiency losses associated with motor under-loading and motor damage incurred during rewinding due to poor practices and materials.

- *Utilization or duty factor.* The portion of assumed operating hours during which the motors on the consumer premises are in service.

- *Load factor.* The average loading of the motor compared to rated capacity.

- *Operation.* The average number of hours per year that motors may be used.

Table 3.6 Electric Motor Stock Accounting

Sector	*Segment*	*Motor Rating (kW)*	*Motor Type*	*Installed Capacity (MW)*	*Segment Share (%)*	*AC Induction Squirrel Cage Share (%)*	*Installed Capacity (MW)*
Residential	All	<7.5	1-phase	17561	65%	100%	17561
Commercial	All	<7.5	1-phase	3808	14%	100%	3808
Industrial	cottage	<7.5	1-phase	4953	18%	100%	4953
Industrial	other LT	<7.5	1-phase	0	0%	100%	0
Industrial	HT	<7.5	1-phase	0	0%	100%	0
Other	All	<7.5	1-phase	890	3%	100%	890
Total		<7.5	1-phase	27,212	100%		27,212
Residential	All	<7.5	3-phase	0	0%	96%	0
Commercial	All	<7.5	3-phase	2289	27%	96%	2193
Industrial	cottage	<7.5	3-phase	4466	52%	96%	4279
Industrial	other LT	<7.5	3-phase	866	10%	96%	829
Industrial	HT	<7.5	3-phase	433	5%	96%	415
Other	All	<7.5	3-phase	535	6%	96%	513
Total		<7.5	3-phase	8,589	100%		8,229
Residential	All	9.3 - 15	3-phase	0	0%	94%	0
Commercial	All	9.3 - 15	3-phase	1062	10%	94%	998
Industrial	cottage	9.3 - 15	3-phase	0	0%	94%	0
Industrial	other LT	9.3 - 15	3-phase	6191	58%	94%	5820
Industrial	HT	9.3 - 15	3-phase	3095	29%	94%	2910
Other	All	9.3 - 15	3-phase	248	2%	94%	233
Total		9.3 - 15	3-phase	10,597	100%		9,961
Residential	All	18.5 - 30	3-phase	0	0%	79%	0
Commercial	All	18.5 - 30	3-phase	0	0%	79%	0
Industrial	cottage	18.5 - 30	3-phase	0	0%	79%	0
Industrial	other LT	18.5 - 30	3-phase	3250	67%	79%	2575
Industrial	HT	18.5 - 30	3-phase	1625	33%	79%	1288
Other	All	18.5 - 30	3-phase	0	0%	79%	0
Total		18.5 - 30	3-phase	4,876	100%		3,863
Residential	All	37 - 45	3-phase	0	0%	58%	0
Commercial	All	37 - 45	3-phase	0	0%	58%	0
Industrial	cottage	37 - 45	3-phase	0	0%	58%	0
Industrial	other LT	37 - 45	3-phase	2552	67%	58%	1481
Industrial	HT	37 - 45	3-phase	1276	33%	58%	740
Other	All	37 - 45	3-phase	0	0%	58%	0
Total		37 - 45	3-phase	3,828	100%		2,221
Residential	All	>45	3-phase	0	0%	48%	0
Commercial	All	>45	3-phase	0	0%	48%	0
Industrial	cottage	>45	3-phase	0	0%	48%	0
Industrial	other LT	>45	3-phase	0	0%	48%	0
Industrial	HT	>45	3-phase	14782	90%	48%	7115
Other	All	>45	3-phase	1694	10%	48%	815
Total		>45	3-phase	16,476	100%		7,930

Table 3.7 Electric Motor Energy Consumption

Sector/ Segment	Motor Rating and Type	AC, Sq. Cage Installed Capacity (MW)	Average Rated Efficiency (%)	Average In-Service Efficiency Derating (%)	Duty Factor (%)	Load Factor (%)	Operation (Hrs/yr)	Energy Use (GWh/yr)
Residential	<7.5, 1ph	17561	70%	0%	70%	100%	2500	43,901
Commercial	<7.5, 1ph	3808	70%	0%	75%	80%	3000	9,793
Ind'l - cottage	<7.5, 1ph	4953	70%	0%	85%	50%	3000	9,021
Ind'l - LT	<7.5, 1ph	0	70%	0%	85%	50%	3000	0
Ind'l - HT	<7.5, 1ph	0	70%	0%	90%	50%	6000	0
Other	<7.5, 1ph	890	70%	0%	90%	50%	4000	2,290
Total	<7.5, 1ph	27,212						65,006
Residential	<7.5, 3ph	0	80%	3%	70%	100%	2500	0
Commercial	<7.5, 3ph	2193	80%	3%	75%	80%	3000	5,127
Ind'l - cottage	<7.5, 3ph	4279	80%	3%	85%	50%	3000	7,085
Ind'l - LT	<7.5, 3ph	829	80%	3%	85%	50%	3000	1,373
Ind'l - HT	<7.5, 3ph	415	80%	3%	90%	50%	6000	1,454
Other	<7.5, 3ph	513	80%	3%	90%	50%	4000	1,199
Total	<7.5, 3ph	8,229						16,239
Residential	9.3 – 15, 3ph	0	88%	5%	70%	100%	2500	0
Commercial	9.3 - 15, 3ph	998	88%	5%	75%	80%	3000	2,165
Ind'l - cottage	9.3 – 15, 3ph	0	88%	5%	85%	50%	3000	0
Ind'l - LT	9.3 - 15, 3ph	5820	88%	5%	85%	50%	3000	8,940
Ind'l - HT	9.3 - 15, 3ph	2910	88%	5%	90%	50%	6000	9,466
Other	9.3 - 15, 3ph	233	88%	5%	90%	50%	4000	506
Total	9.3 - 15, 3ph	9,961						21,076
Residential	18.5 - 30, 3ph	0	90%	6%	70%	100%	2500	0
Commercial	18.5 - 30, 3ph	0	90%	6%	75%	80%	3000	0
Ind'l - cottage	18.5 - 30, 3ph	0	90%	6%	85%	50%	3000	0
Ind'l - LT	18.5 - 30, 3ph	2575	90%	6%	85%	50%	3000	3,909
Ind'l - HT	18.5 - 30, 3ph	1288	90%	6%	90%	50%	6000	4,139
Other	18.5 - 30, 3ph	0	90%	6%	90%	50%	4000	0
Total	18.5 - 30, 3ph	3,863						8,048
Residential	37 - 45, 3ph	0	93%	6%	70%	100%	2500	0
Commercial	37 - 45, 3ph	0	93%	6%	75%	80%	3000	0
Ind'l - cottage	37 - 45, 3ph	0	93%	6%	85%	50%	3000	0
Ind'l - LT	37 - 45, 3ph	1481	93%	6%	85%	50%	3000	2,170
Ind'l - HT	37 - 45, 3ph	740	93%	6%	90%	50%	6000	2,298
Other	37 - 45, 3ph	0	93%	6%	90%	50%	4000	0
Total	37 - 45, 3ph	2,221						4,468
Residential	>45, 3ph	0	94%	6%	70%	100%	2500	0
Commercial	>45, 3ph	0	94%	6%	75%	80%	3000	0
Ind'l - cottage	>45, 3ph	0	94%	6%	85%	50%	3000	0
Ind'l - LT	>45, 3ph	0	94%	6%	85%	50%	3000	0
Ind'l - HT	>45, 3ph	7115	94%	6%	90%	50%	6000	21,831
Other	>45, 3ph	815	94%	6%	90%	50%	4000	1,667
Total	>45, 3ph	7,930						23,498

Section 4 Technical EE Potential Assessment

This section presents the technical EE potential for each of the assessed EE products. Table 4.1 summarizes the results. The assumptions that underlie each of the assessed products are described in the sub-sections that follow.

Table 4.1 Summary of Technical EE Potential Assessment

Energy Efficient Product	*Technical Potential (GWh/yr)*
Compact Fluorescent Lamp (CFL)	13,636
T8 Fluorescent Lamp	1,150
EE Magnetic Ballast	2,130
Electronic Ballast	3,766
T5 Fluorescent Lamp and Ballast	7,208
EE Refrigerator	9,077
EE Room Air Conditioner	1,687
EE Ceiling Fans	4,089
EE Motor (standard replacement)	7,382
EE Motor (in place of rewinding)	13,241

4.1 Compact Fluorescent Lamp

The technical potential for annual energy savings is summarized in Table 4.2, using the methodology described previously. The following input data and assumptions are used in the assessment:

- *Potential sites.* The number of potential CFL applications, as GLS replacements, is taken as the total number of GLS light points.

- *Technically feasible conversions.* The analysis assumes that 80 percent of GLS light points may be feasibly converted to CFLs, without making relatively costly changes to the light fixture, in the residential, industrial and other sectors, while 70 percent can be converted in the commercial sector.[7]

- *Lamp rating comparison.* Whereas the average GLS lamp size is 70 watts, the expected replacement CFL is evaluated at 21 watts. This assumption follows the "3-to-1" comparison standard. The 21-watt CFL will provide more light output than the 70-watt GLS lamp. Whereas incandescent-to-CFL conversions can provide up to 80

[7] The cap / base size of all incandescent lamps (up to 100 watts) is the same, and poses no compatibility problems for conversion to CFLs. However, there are cases where the existing fixture / shade / luminaire cannot be used to house the somewhat longer CFL. Against this background, it may be conservatively estimated that 80% of all GLS sites can be converted to CFL. In the commercial sector, where there are specific applications (e.g., dimming applications, focused lighting, etc.), the overall compatibility is expected to be somewhat less. It is conservatively assumed that 70% of GLS sites in the commercial sector can be converted to CFL.

percent savings, market studies have shown that consumers tend to choose the slightly higher output lamp than the GLS being replaced, benefiting from both energy savings and enhanced lighting. The net unit savings are 70 – 21 = 49 watts.

- *Utilization and operation.* Consumers are assumed not to change their lamp use practices upon changing a lamp from GLS to CFL. The assumptions are the same as those indicated in the appliance stock and energy consumption analysis.

Table 4.2 Compact Fluorescent Lamps - Technical EE Potential

Sector	*Potential Sites (millions)*	*Technically Feasible Conversions (%)*	*Technically Feasible EE Installations (millions)*	*Unit Demand Savings (watts)*	*Utilization (%)*	*Operation (Hrs/yr)*	*Energy Savings (Technical Potential) (GWh/yr)*
Residential	270	80%	216	49	75%	1400	11,113
Commercial	18	70%	13	49	60%	3000	1,111
Industrial	6	80%	5	49	90%	3000	635
Other	6	80%	5	49	83%	4000	776
Total							13,636

4.2 T8 Fluorescent Lamp

The technical potential for annual energy savings is summarized in Table 4.3, using the following input data and assumptions:

- *Potential sites.* The number of potential T8 applications is assumed to be the total number of fluorescent (FTL) light points less the number of T8 lamps that are already on the market. The current T8 market share is estimated by suppliers to be 10 percent. The number of potential new T8 applications, toward assessing remaining technical potential, is 90 percent of the number of FTL light points, referencing the stock evaluated in the stock accounting and energy consumption analysis.

- *Technically feasible conversions.* The analysis assumes that 90 percent of FTL light points may be feasibly converted to T8s. The 10 percent that are not feasible applications include special purpose (e.g., starting or color characteristics) or odd-sized lamps, which have a sufficiently small market share that it is not worthwhile for manufacturers to change equipment to manufacture them in the T8 size.

- *Lamp rating comparison.* Whereas the typical FTL lamp rating is 40 watts, the replacement T8 is rated at 36 watts. Both lamps may be operated with the same magnetic ballast, with no difference in energy impact. The net savings in lamp energy requirement is 4 watts.[8]

[8] T8 lamps are available with a tri-phosphate coating that improves light output and offers other benefits including better color rendition and reduced lumen depreciation. These lamps are the focus of FTL conversion promotional programs in North America and Europe, particularly as their replacement must also

- *Utilization and operation.* Consumers are assumed not to change their lamp use practices after lamp conversion. The assumptions are the same as those indicated in the appliance stock and energy consumption analysis.

Table 4.3 T8 Fluorescent Lamps - Technical EE Potential

Sector	Potential Sites (millions)	Technically Feasible Conversions (%)	Technically Feasible EE Installations (millions)	Unit Demand Savings (watts)	Utilization (%)	Operation (Hrs/yr)	Energy Savings (Technical Potential) (GWh/yr)
Residential	68	90%	62	4	90%	1400	311
Commercial	67	90%	61	4	60%	3000	437
Industrial	24	90%	22	4	90%	3500	276
Other	11	90%	10	4	83%	4000	127
Total							1,150

4.3 Energy Efficient Electromagnetic Ballasts

The technical potential for annual energy savings is summarized in Table 4.4. The technical potential assessment for EE electromagnetic (EE-EM) ballasts includes the following input data and assumptions:

- *Potential sites.* As in the analysis for T8 fluorescent lamps, the number of potential EE-EM ballast applications is assumed to be the total number of fluorescent (FTL) light points less the number of such ballasts that are already on the market. This approach assumes that each FTL light point requires one ballast to drive the lamp, i.e., that essentially no ballasts drive two or more lamps. This is typical of lighting practice in the Indian market. Manufacturers in the organized sector claim that the current market share of EE-EM ballasts is essentially zero. The gray market supplies the great majority (90+ percent) of ballasts, which are thus unbranded products.

- *Technically feasible conversions.* The analysis assumes that 100 percent of the standard FTL ballasts light points may be feasibly converted to EE-EM ballasts

- *Ballast energy loss comparison.* The typical standard ballast is assumed to require 15 watts. This is a conservative assumption because the majority of the ballasts on the market are inferior quality, gray market products, and losses may be as high as 20 watts. However, the distribution of ballast quality and associated in the market is not

entail installation of electronic ballast, further reducing the power requirement. However, their market penetration is very slight in most developing countries, even those with very high standard T8 penetration, and the tri-phosphate-coated T8 lamps are generally reserved for special applications due to their color rendition benefits. The reason for this is that while a standard T8 lamp has comparable cost to the existing T12 FTL lamp, the tri-phosphate-coated T8 sells for double the cost or more. The electronic ballast increases the installation cost further, particularly in countries such as India where FTL fixtures typically hold just one lamp, requiring a ballast for each T8, whereas in countries such as the USA fixtures typically hold two to four lamps, and each ballast can operate two lamps or more.

known. The 15-watt loss figure is consistent with assumptions in the EMCAT report. EE-EM ballasts have rated losses of 9 watts, yielding a loss reduction of at least 6 watts per ballast replacement.

- *Utilization and operation.* Consumers are assumed not to change their lamp use practices after lamp conversion. The assumptions are the same as those indicated in the appliance stock and energy consumption analysis.

Table 4.4 Energy Efficient Electromagnetic Ballasts - Technical EE Potential

Sector	*Potential Sites (millions)*	*Technically Feasible Conversions (%)*	*Technically Feasible EE Installations (millions)*	*Unit Demand Savings (watts)*	*Utilization (%)*	*Operation (Hrs/yr)*	*Energy Savings (Technical Potential) (GWh/yr)*
Residential	76	100%	76	6	90%	1400	575
Commercial	75	100%	75	6	60%	3000	810
Industrial	27	100%	27	6	90%	3500	511
Other	12	100%	12	6	83%	4000	234
Total							2,130

4.4 Electronic Ballasts

The technical potential for annual energy savings is summarized in Table 4.5. The technical potential assessment for electronic ballasts includes the following input data and assumptions:

- *Potential sites.* The assessment of potential sites is identical to that for EE-EM ballasts.

- *Technically feasible conversions.* Electronic ballasts are smaller in size than standard ballasts and present some compatibility constraints, due primarily to the existing fittings, and also potentially due to sensitivity in situations of very poor power quality. Fixture constraints are expected to be greatest in the commercial sector, and only slight in the industrial sector, as indicated in Table 4.5.

- *Ballast energy loss comparison.* Electronic ballasts require only 2 watts each. They provide a 13-watt savings compared to the 15-watt loss assumed for the standard ballast.

- *Utilization and operation.* Consumers are assumed not to change their lamp use practices after lamp conversion. The assumptions are the same as those indicated in the appliance stock and energy consumption analysis.

Table 4.5 Electronic Ballasts - Technical EE Potential

Sector	Potential Sites (millions)	Technically Feasible Conversions (%)	Technically Feasible EE Installations (millions)	Unit Demand Savings (watts)	Utilization (%)	Operation (Hrs/yr)	Energy Savings (Technical Potential) (GWh/yr)
Residential	76	80%	61	13	90%	1400	997
Commercial	75	75%	56	13	60%	3000	1,315
Industrial	27	90%	24	13	90%	3500	997
Other	12	90%	11	13	83%	4000	457
Total							3,766

4.5 T5 Fluorescent Lamps with Electronic Ballasts

The T5 fluorescent lamp is a new product with higher efficacy than either T12 or T8 lamps. It has been introduced to the Indian market only very recently, in 1999 or 2000. It is being marketed in two forms. As a replacement for existing FTL lamps, the shorter T5 lamp is marketed with an integral electronic ballast and fitting that effectively lengthens the tube and allows its installation in the existing FTL luminaire. The T5 lamp is also marketed with a companion luminaire that maximizes the photometric characteristics of the lamp, improving the efficacy. This latter product is positioned for the new construction market or as replacement for existing FTL luminaries.

Data for the T5 products being marketed today in India are not available, and the estimates below were based upon international product data and intended to indicate the EE potential of this product pending future investigation. The following assumptions pertain to the technical potential assessment:

- *Potential sites.* The assessment of potential sites is identical to that for T8 lamps.

- *Technically feasible conversions.* The analysis assumes that only standard length tubes would be converted (T40 size) and that this size represents 70 percent of the FTL market.

- *Lamp-ballast energy consumption comparison.* The T5 lamp and electronic ballast combination is assumed to require 26 watts compared to the conventional combination of T12 lamp and magnetic ballast which requires 55 watts. The lamp efficacy of the T5 lamp is approximately 100 lumens per watt, whereas that for the T12 lamp is in the range of 50-65 lumens per watt.

- *Utilization and operation.* Consumers are assumed not to change their lamp use practices after lamp conversion. The assumptions are the same as those indicated in the appliance stock and energy consumption analysis.

Table 4.6 T5 Fluorescent Lamp & Electronic Ballast - Technical EE Potential

Sector	Potential Sites (millions)	Technically Feasible Conversions (%)	Technically Feasible EE Installations (millions)	Unit Demand Savings (watts)	Utilization (%)	Operation (Hrs/yr)	Energy Savings (Technical Potential) (GWh/yr)
Residential	76	70%	53	29	90%	1400	1,946
Commercial	75	70%	52	29	60%	3000	2,739
Industrial	27	70%	19	29	90%	3500	1,730
Other	12	70%	8	29	83%	4000	793
Total							7,208

4.6 Energy Efficient Refrigerators

The technical potential for annual energy savings is summarized in Table 4.7. The technical potential assessment for EE refrigerators includes the following input data and assumptions:

- *Potential sites.* The entire stock of refrigerators represents the scope of potential sites. EE models have been available on the market for years, and their market share is assessed at 5 percent, which is consistent with the EMCAT report. The number of potential sites was assessed at 95 percent of the appliance stock.

- *Technically feasible conversions.* There is no issue of technical incompatibility with respect to replacement of standard refrigerators. However, consistent with the EMCAT report, 10 percent of refrigerators are assumed not to be compatible with existing applications. They may be considered to represent models with added features that themselves require additional energy.

- *Energy consumption comparison.* The energy efficiency is evaluated by comparison of daily energy consumption. The average daily consumption of refrigerators in the appliance stock was estimated to be 1.7 kwh/day for the standard, 165-liter model in the residential sector, as indicated in the stock accounting and energy consumption section. The EE refrigerator was assumed to require 0.5 kwh/day, which is the rated value for the highest efficiency refrigerators available on the Thai and South Korean markets,[9] for example, although the most efficient Indian refrigerators available currently are rated at 0.9 kwh/day. The potential energy reduction was thus assumed to be 1.2 kwh/day.[10]

[9] This rating corresponds to the energy consumption of 185-liter models, rated at 200 kwh/year annual consumption.

[10] Indian manufacturers claim that one of the reasons that their refrigerators are less efficient than other Asian models is that they must oversize the compressor to avoid premature equipment failure under poor power quality conditions.

- *Utilization and operation.* Consumers are assumed not to change their appliance use practices after purchasing an EE model. The assumptions are the same as those indicated in the appliance stock and energy consumption analysis.

Table 4.7 Energy Efficient Refrigerators - Technical EE Potential

Sector	Potential Sites (millions)	Technically Feasible Conversions (%)	Technically Feasible EE Installations (millions)	Unit Energy Savings (kWh/day)	Utilization (%)	Operation (Days/yr)	Technical Energy Savings Potential (GWh/yr)
Residential	23	90%	20	1.7	100%	365	8,608
Commercial	1	90%	1	1.9	100%	365	470
Total							9,077

4.7 Energy Efficient Room Air Conditioning Units

The technical potential for annual energy savings is summarized in Table 4.8. The technical potential assessment for EE air conditioning units includes the following input data and assumptions:

- *Potential sites.* The entire stock of unitary air conditioners, 0.8 million, represents the scope of potential sites. The existing market share of EE models is assessed at 1 percent, as it is essentially nil, although such models are available from all Indian manufacturers.

- *Technically feasible conversions.* Consistent with the EMCAT report, 10 percent of existing units are assumed not to be compatible with EE units, due to features that lead to higher energy use.

- *Energy consumption comparison.* The reported unit energy savings assumes that the average unit in the existing stock has a COP of 9.0, while the energy efficient unit has a COP of 10.0, which is available on the Indian market.
- *Utilization and operation.* Consumers are assumed not to change their appliance use practices after purchase of an EE model. The assumptions are the same as those indicated in the appliance stock and energy consumption analysis.

Table 4.8 Energy Efficient Room Air Conditioning Units - Technical EE Potential

Sector	Potential Sites (millions)	Technically Feasible Conversions (%)	Technically Feasible EE Installations (millions)	Unit Energy Savings (W)	Utilization (%)	Operation (Days/yr)	Technical Energy Savings Potential (GWh/yr)
Residential	0.8	90%	0.7	639	100%	365	750
Commercial	0.8	90%	0.7	639	100%	365	937
Total							1,687

4.8 Energy Efficient Ceiling Fans

The technical potential for annual energy savings is summarized in Table 4.9. The assessment includes the following input data and assumptions:

- *Potential sites.* The entire stock of ceiling fans represents the scope of potential sites. The existing market share of EE models is assumed to be nil, because the energy efficient motors of this size are not currently available from Indian manufacturers.
- *Technically feasible conversions.* All existing ceiling fans can be replaced with the EE units.
- *Energy consumption comparison.* Whereas fan efficient improvement potential has been reported to be in the range of 10 to 20 percent, this analysis assumes the potential to be 15 percent of the existing 70-watt power requirement.[11]
- *Utilization and operation.* Consumers are assumed not to change their appliance use practices after purchase of an EE model. The assumptions are the same as those indicated in the appliance stock and energy consumption analysis.

Table 4.9 Energy-Efficient Ceiling Fans – Technical EE Potential

Sector	*Potential Sites (Millions)*	*Technically Feasible Conversions (%)*	*Technically Feasible EE Installations (Millions)*	*Unit Energy Savings (W)*	*Utilization (%)*	*Operation (Hrs/yr)*	*Technical Energy Savings Potential (GWh/yr)*
Residential	132.9	100%	132.9	11	100%	2500	3,488
Commercial	6.8	100%	6.8	11	100%	2500	179
Industrial	6.8	100%	6.8	11	100%	2500	179
Institutional	9.2	100%	9.2	11	100%	2500	243
Total	156		156				4,089

4.9. Energy Efficient Motors

The technical potential for EE motors was developed in two cases. The first case considers the energy impact of using an EE motor rather than a standard motor whenever an existing motor is replaced. In this case, the incremental savings is the result of the difference in energy efficiency between an EE motor and a new standard efficiency motor.

The second case considers the energy impact of replacing each existing motor with an EE motor when it fails. In this case, whereas the existing motor would typically be repaired rather than replaced, perpetuating or worsening its already degraded level of efficiency, the consumer would replace it. The incremental energy savings in this case is the difference in energy efficiency between the EE motor and the motor that is currently in service.

[11] *ACEEE, p70-71.*

The two cases are presented separately below:

In both cases, the analysis compares the efficiency level of EE and standard motors that are currently available from Indian manufacturers. Indian EE motors are less efficient than some foreign models, generally by 0.5 percent to 2 percent depending upon the motor size. This difference is due to the lack of specialized materials required in motor construction to gain the incremental efficiency level. Until recently, import restrictions made foreign EE motors unavailable in India. While imported EE motors are technically available per the claims of traders, their market penetration is nil and it is difficult to estimate what the incremental price would be compared to domestically produced motors, if imports gained market share. But if demand for imported motors gained sufficiently, it is more likely that Indian manufacturers would acquire the materials and facilities to produce the higher efficiency motor. Assessment of the likely cost of such a motor is left to another analysis. This evaluation focuses on the comparison of locally produced standard and EE motors.

Case 1: New Standard-to-EE Motor Substitution at Motor Replacement

The input data and assumptions used to estimate technical EE potential are summarized in Table 4.10 and described as follows:

- *Technically feasible EE motor installations.* Due to factors such as motor mounting requirements and special applications, 20 percent of the potential applications are assumed not to be technically feasible for EE motor substitution. The indicated amounts are 80 percent of the total installed capacity of AC induction, squirrel cage motors as listed in Table 3.6.

- *Standard replacement motor efficiency.* The rated efficiency of standard motors is as reported by Indian manufacturers.

- *EE unit efficiency increment.* The incremental efficiency gain represented by the rated efficiency of EE motors compared to standard motors, as reported by Indian manufacturers.

- *Utilization and operation.* Consumers are assumed not to change their motor use practices after changing the motor. The assumptions are the same as those indicated in the appliance stock and energy consumption analysis.

Table 4.10 Energy Efficient Motors Case 1 - Technical EE Potential

Sector/ Segment	*Motor Rating and Type*	*Technically Feasible EE Installations (MW)*	*Standard Replace-ment Unit Efficiency (%)*	*EE Unit Efficiency Increment (%)*	*Duty Factor (%)*	*Load Factor (%)*	*Operation (Hrs/yr)*	*Energy Use (GWh/yr)*
Residential	<7.5, 1ph	14,048	72%	10%	70%	100%	2500	4,164
Commercial	<7.5, 1ph	3,047	72%	10%	75%	80%	3000	929
Ind'l - cottage	<7.5, 1ph	3,962	72%	10%	85%	50%	3000	927
Ind'l - LT	<7.5, 1ph	0	72%	10%	85%	50%	3000	0
Ind'l - HT	<7.5, 1ph	0	72%	10%	90%	50%	6000	0
Other	<7.5, 1ph	712	72%	10%	90%	50%	4000	235
Total	<7.5, 1ph							6,255
Residential	<7.5, 3ph	0	85%	3%	70%	100%	2500	0
Commercial	<7.5, 3ph	1,755	85%	3%	75%	80%	3000	127
Ind'l - cottage	<7.5, 3ph	3,423	85%	3%	85%	50%	3000	183
Ind'l - LT	<7.5, 3ph	664	85%	3%	85%	50%	3000	36
Ind'l - HT	<7.5, 3ph	332	85%	3%	90%	50%	6000	38
Other	<7.5, 3ph	410	85%	3%	90%	50%	4000	31
Total	<7.5, 3ph							414
Residential	9.3 – 15, 3ph	0	89%	2%	70%	100%	2500	0
Commercial	9.3 - 15, 3ph	799	89%	2%	75%	80%	3000	35
Ind'l - cottage	9.3 – 15, 3ph	0	89%	2%	85%	50%	3000	0
Ind'l - LT	9.3 - 15, 3ph	4,656	89%	2%	85%	50%	3000	150
Ind'l - HT	9.3 - 15, 3ph	2,328	89%	2%	90%	50%	6000	159
Other	9.3 - 15, 3ph	187	89%	2%	90%	50%	4000	8
Total	9.3 - 15, 3ph							353
Residential	18.5 - 30, 3ph	0	91%	2%	70%	100%	2500	0
Commercial	18.5 - 30, 3ph	0	91%	2%	75%	80%	3000	0
Ind'l - cottage	18.5 - 30, 3ph	0	91%	2%	85%	50%	3000	0
Ind'l - LT	18.5 - 30, 3ph	2,060	91%	2%	85%	50%	3000	64
Ind'l - HT	18.5 - 30, 3ph	1,030	91%	2%	90%	50%	6000	68
Other	18.5 - 30, 3ph	0	91%	2%	90%	50%	4000	0
Total	18.5 - 30, 3ph							132
Residential	37 - 45, 3ph	0	93%	1%	70%	100%	2500	0
Commercial	37 - 45, 3ph	0	93%	1%	75%	80%	3000	0
Ind'l - cottage	37 - 45, 3ph	0	93%	1%	85%	50%	3000	0
Ind'l - LT	37 - 45, 3ph	1,185	93%	1%	85%	50%	3000	18
Ind'l - HT	37 - 45, 3ph	592	93%	1%	90%	50%	6000	19
Other	37 - 45, 3ph	0	93%	1%	90%	50%	4000	0
Total	37 - 45, 3ph							37
Residential	>45, 3ph	0	94%	1%	70%	100%	2500	0

Commercial	>45, 3ph	0	94%	1%	75%	80%	3000	0
Ind'l - cottage	>45, 3ph	0	94%	1%	85%	50%	3000	0
Ind'l - LT	>45, 3ph	0	94%	1%	85%	50%	3000	0
Ind'l - HT	>45, 3ph	5,692	94%	1%	90%	50%	6000	178
Other	>45, 3ph	652	94%	1%	90%	50%	4000	14
Total	>45, 3ph							191
Total	All motors							7382

Case 2: Existing-to-EE Motor Substitution Instead of Motor Rewinding

The input data and assumptions used to estimate technical EE potential are summarized in Table 4.11 and described as follows:

- *Technically feasible EE motor installations.* The assumption is the same as in Case 1.
- *Standard replacement motor efficiency.* The rated efficiency of standard motors is as reported by Indian manufacturers.
- *EE unit efficiency increment.* The incremental efficiency gain represented by the rated efficiency of EE motors compared to standard motors, as reported by Indian manufacturers.[12]
- *Utilization and operation.* Consumers are assumed not to change their motor use practices after changing the motor. The assumptions are the same as those indicated in the appliance stock and energy consumption analysis.

Table 4.11 Energy Efficient Motors Case 2 - Technical EE Potential

Sector/ Segment	Motor Rating and Type	Technically Feasible EE Installations (MW)	Existing Unit Average Efficiency (%)	EE Unit Efficiency Increment (%)	Duty Factor (%)	Load Factor (%)	Operation (Hrs/yr)	Energy Use (GWh/yr)
Residential	<7.5, 1ph	14,048	70%	12%	70%	100%	2500	5,140
Commercial	<7.5, 1ph	3,047	70%	12%	75%	80%	3000	1,147
Ind'l - cottage	<7.5, 1ph	3,962	70%	12%	85%	50%	3000	1,145
Ind'l - LT	<7.5, 1ph	0	70%	12%	85%	50%	3000	0
Ind'l - HT	<7.5, 1ph	0	70%	12%	90%	50%	6000	0
Other	<7.5, 1ph	712	70%	12%	90%	50%	4000	291
Total	<7.5, 1ph							7,722
Residential	<7.5, 3ph	0	77%	11%	70%	100%	2500	0
Commercial	<7.5, 3ph	1,755	77%	11%	75%	80%	3000	513
Ind'l - cottage	<7.5, 3ph	3,423	77%	11%	85%	50%	3000	744
Ind'l - LT	<7.5, 3ph	664	77%	11%	85%	50%	3000	144
Ind'l - HT	<7.5, 3ph	332	77%	11%	90%	50%	6000	153
Other	<7.5, 3ph	410	77%	11%	90%	50%	4000	126
Total	<7.5, 3ph							1,680
Residential	9.3 – 15, 3ph	0	83%	8%	70%	100%	2500	0

[12] Note that where the motor load factor is 50 percent or less (i.e., the motor is considerably oversized), a further efficiency loss is assessed for both EE and standard motors. This load-related efficiency loss ranges from 1 to 3 percent depending upon motor size.

Commercial	9.3 - 15, 3ph	799	83%	8%	75%	80%	3000	152
Ind'l - cottage	9.3 – 15, 3ph	0	83%	8%	85%	50%	3000	0
Ind'l - LT	9.3 - 15, 3ph	4,656	83%	8%	85%	50%	3000	643
Ind'l - HT	9.3 - 15, 3ph	2,328	83%	8%	90%	50%	6000	681
Other	9.3 - 15, 3ph	187	83%	8%	90%	50%	4000	36
Total	9.3 - 15, 3ph							1,513
Residential	18.5 - 30, 3ph	0	84%	9%	70%	100%	2500	0
Commercial	18.5 - 30, 3ph	0	84%	9%	75%	80%	3000	0
Ind'l - cottage	18.5 - 30, 3ph	0	84%	9%	85%	50%	3000	0
Ind'l - LT	18.5 - 30, 3ph	2,060	84%	9%	85%	50%	3000	310
Ind'l - HT	18.5 - 30, 3ph	1,030	84%	9%	90%	50%	6000	328
Other	18.5 - 30, 3ph	0	84%	9%	90%	50%	4000	0
Total	18.5 - 30, 3ph							637
Residential	37 - 45, 3ph	0	87%	7%	70%	100%	2500	0
Commercial	37 - 45, 3ph	0	87%	7%	75%	80%	3000	0
Ind'l - cottage	37 - 45, 3ph	0	87%	7%	85%	50%	3000	0
Ind'l - LT	37 - 45, 3ph	1,185	87%	7%	85%	50%	3000	132
Ind'l - HT	37 - 45, 3ph	592	87%	7%	90%	50%	6000	140
Other	37 - 45, 3ph	0	87%	7%	90%	50%	4000	0
Total	37 - 45, 3ph							272
Residential	>45, 3ph	0	88%	7%	70%	100%	2500	0
Commercial	>45, 3ph	0	88%	7%	75%	80%	3000	0
Ind'l - cottage	>45, 3ph	0	88%	7%	85%	50%	3000	0
Ind'l - LT	>45, 3ph	0	88%	7%	85%	50%	3000	0
Ind'l - HT	>45, 3ph	5,692	88%	7%	90%	50%	6000	1,316
Other	>45, 3ph	652	88%	7%	90%	50%	4000	100
Total	>45, 3ph							1,416
Total	All motors							13,241

Section 5 Consumer Issues Affecting Product Choice

The objective of the following analysis is to gain a preliminary understanding of the issues facing the consumer community that would need to be addressed before the demand for EE products can increase. The analysis is drawn from secondary sources, interviews with vendors and suppliers, and the professional judgment of the study team, though without the benefit of detailed, statistically based consumer or market research.

For each of the products evaluated in the technical EE potential analysis, the study team considered the following aspects of consumer purchase behavior:

- Who are the potential customers of the selected EE products?
- What products do these potential customers buy now?
- Why and how do the potential customers select their purchases?
- When do the potential customers purchase the products, including seasonal buying habits or other factors that may affect purchases?
- What would induce consumers to substitute EE products for the products they buy now?

Clearly, future market research will refine this analysis to a large degree, and may likely change some of the conclusions. In particular, regional differences—in consumer preferences, product offerings, distribution channels, manufacturers, and factors that affect consumer choice such as climate and electricity tariffs—may have considerable influence on the local prospects for increasing market share for some EE products. This dimension of EE market development in India is left for a future study.

5.1. Compact Fluorescent Lamps

Compact fluorescent lamps (CFLs) are generally regarded as a substitute for GLS lamps. The CFL market share, in terms of the number of CFL light points compared to GLS light points, is about 10 percent. But CFL market penetration is not widely distributed. The greatest market penetration appears to be in the commercial sector, where CFLs are estimated to have essentially equaled the share of GLS light points. However, in the residential sector where the market potential is greatest in terms of GLS light points, CFL market penetration is estimated to be low, at less than 2 percent.

The following assessment considers the market for CFLs by consumer sectors: residential, commercial, industrial, and other (primarily institutional). Each sector analysis considers the five questions about consumer behavior identified previously.

Residential Consumer Market

Lighting preferences vary considerably among households. They are stratified principally by income level, although rural consumers also have limited choice available in their local markets. Table 5.1 *summarizes the market* characteristics.

In urban areas, some brands have stronger presence in a region over the other brands. However, for most consumer segments, GLS lamps are purchased without any concern for brand. Those consumers with brand preferences have generally developed them through adverse experience with a particular brand with respect to lamp life.

Table 5.1 GLS & CFL Market Characteristics: Residential Sector

Consumer Segment	*Current Product Choice*	*Reasons for Purchase Choice*[13]	*Where Products are Purchased*	*Potential EE Market Shift Inducements*
Urban High Income	Prefer GLS	Prefer light quality of GLS over FTL and CFL.	Retail shops selling electrical goods.	Improve awareness of EE benefits, best applications.
Urban Upper Middle Income	GLS and CFL	CFL is perceived to be in fashion; not purchased for energy efficiency benefits.	Retail shops selling electrical goods.	Improve awareness of EE benefits.
Urban Middle and Lower Income	GLS	Prefer GLS due to low cost; CFL too expensive. Brand-conscious for lamp life considerations. Suspect manufacturer claims about CFL life, and want explicit replacement guarantees from manufacturers.	Retail shops selling electrical goods.	Interventions to reduce CFL price to consumers or assistance with financing. Promotion for CFL lifetime benefits.
Rural (Primarily Low Income)	GLS	Cost-oriented. Rural consumers have no access to CFL and little access to good quality GLS lamps. They buy low quality GLS lamps manufactured locally, costing a fraction of the price of branded GLS lamps, though lasting as little as a few weeks.	Retail shops selling electrical goods.	Consumer education relating to product characteristics. Financial assistance. Difficult to penetrate sustainably due to limited EE benefits with low tariff.

A consumer survey in the Delhi area was an important source for the market summary indicated in Table 5.1. [14] The majority of survey respondents were from high-income groups (85 percent of respondents classified as upper middle income or higher). In this high income group, 19 percent of respondents have used a CFL, while 34 percent of middle income respondents have used a CFL. This survey also asked consumers for their reasons for not using CFLs, and results are shown in Table 5.2.

[13] Source: 43,44,45,46,47.

[14] "Constraints In Marketing Of Energy Efficient Equipment: Case Study Of CFLs," Dr S K Join, IIT Delhi. The area covered included Delhi and NOIDA (district Gautam Budh Nagar), Ghaziabad, Faridabad and Gurgaon. Out of a sample of nearly 900 households, there were 204 respondents.

Table 5.2 Survey Results: Why Residential Consumers Do Not Buy CFLs

Consumer Segment	*Share of Total Respondents*	*Unaware of CFLs*	*CFLs Are Too Expensive*	*Distrust Claims About CFL Lifetime*
Upper Middle and Higher Income	85%	39%	22%	23%
Middle Income and Lower	15%	24%	28%	16%

Commercial, Industrial, and Institutional Consumer Markets

Whereas the residential sector is estimated to have over 80 percent of the combined GLS/CFL market, the remainder is shared by the commercial, industrial, and institutional (other) sectors. The commercial sector has the majority share among them. Table 5.3 summarizes their market characteristics.

Table 5.3 GLS and CFL Market Characteristics: Non-Residential Consumers

Consumer Segment	*Current Product Choice*	*Reasons for Purchase Choice*[15]	*Where Products are Purchased*	*Potential EE Market Shift Inducements*
Commercial	GLS and CFL	Select CFL for reduced operating cost (energy savings) and high lumen output	Small: retail shops Large: direct from manufacturers or distributors via open negotiations or quotation.	Barriers limited. Promotion to improve awareness in remaining segments.
Industrial: Small/Cottage	GLS	Low price of GLS lamps	Retail shops	Improve awareness of net EE benefits.
Industrial: Low Tension	GLS	Low price of GLS lamps	Retail shops	Improve awareness of net EE benefits.
Industrial: High Tension	GLS and CFL	GLS for color or other specific functional advantages. CFL for energy savings and long life.	Direct from manufacturers or distributors via open negotiations or quotation.	Interventions not necessary.
Institutional	GLS	Do not select CFLs due to high cost, lack of awareness or verification of CFL benefits, and fear of lamp theft.	Tender procedure, awards based on lowest cost.	Awareness building and modification to procurement rules.

Commercial buyers have responded most to the introduction of CFLs, and are estimated to account for more than 60 percent of CFL sales. They are used throughout the sector, in hotels, showrooms, department stores, retail shops, etc., taking advantage of both energy savings and high lumen output compared to GLS lamps. A comparison of CFL sales

[15] Source: 43,44,45,46,47.

levels to GLS light points suggests that much of the CFL penetration potential in the commercial market may have already been achieved.

Market penetration in the industrial sector has been limited due to color rendition issues, and generally by the relatively limited use of GLS lamps except in the small industry segment.

The consumer survey and study cited previously evaluated also the market for CFLs in the institutional sector, surveying 37 institutions. The respondents provided the following reasons for not buying CFLs (including multiple responses):

- 40 percent—Tube lights already installed
- 24 percent—Very expensive
- 24 percent—High chance of theft
- 24 percent—insufficient information
- 3 percent—lack of confidence in claimed savings

CFL Market Conclusions

It appears that CFL marketers have already achieved good penetration in the most promising markets: commercial and large industrial consumers. The small-scale and medium-scale (low tension) industrial sectors may have the most remaining potential out of those markets where CFL energy savings have sufficient value to pay for their cost premium. These remaining industrial consumers appear to prefer GLS lamps due to their sensitivity to first cost, and are unaware or skeptical of net lifecycle benefits.

The institutional sector has promising potential but may require changes to procurement practices, as low-cost-oriented purchasing considers first costs rather than lifecycle costs, preventing CFL purchases.

The middle and lower income residential segments represent by far the largest market potential for CFLs, but cost considerations would necessitate financial assistance to shift consumer buying habits.

5.1 T8 Fluorescent Lamps

Fluorescent lighting accounts for more than one third of all light points in India, and is widely distributed among all the consumer segments. Nearly 90 percent of the FTL lamps in service are the T12 type. T8 lamps are generally a feasible replacement, for a 10 percent energy savings. Moreover, T8 lamps are slightly less expensive than T12 lamps. These factors alone would suggest that T8 lamps should capture the FTL market quickly, with no intervention required. However, various barriers have prevented T8 market penetration.

Barriers to T8 Market Penetration

Although no studies have been performed to differentiate consumer preferences among the market segments, this study team's interactions with manufacturers has indicated that the barriers are generally common to all sector segments. The barriers to T8 market penetration include the following:

- *Awareness.* Many consumers are not aware of the availability of T8 lamps, nor their energy savings benefits. Also many distributors are not aware of the energy efficiency benefits of T8 lamps

- *Perception of reduced lamp life.* Consumers believe that when an FTL develops black marks on its ends, it will soon burn out. Anode rings are more prominent on the small diameter T8 than on the T12. Consumers associate the darkish rings of the T8 as a sign of being worn out or having little remaining life.

- *Perceived incompatibility with poor power quality.* When the T8 was first introduced in India, it suffered from starting problems under low-voltage power supply. While this problem has been corrected,[16] the consumers still believe that T8 lamps are not suitable where the power supply is subject to low voltage, which applies to much of India.

- *Perception of reduced light output.* Consumers associate the reduced wattage and smaller diameter tube of the T8 with less light output, regardless of manufacturer specifications that indicate equivalent light output to the T12.

- *Perception of more rapid lumen depreciation.* Consumers are reported to believe that the T8 suffers from faster depreciation of lumen output than the T12, despite manufacturer specifications to the contrary.

Steps Required to Overcome Market Barriers

The T8 lamp is unusual compared to other energy efficient product substitutes in that it actually costs less than its standard counterpart. The principal market barriers to be overcome are perceptions of poor product quality and insufficient awareness of the energy efficiency benefits.

An important issue is whether consumer perceptions of inferior quality are true, despite manufacturer claims in the product specifications. The industry needs to confront this issue, perhaps with the participation of an independent testing facility, and prove or

[16] The IS standard specifies the voltage range in which FTL lamps (T8 and T12) should function. The low end of that range is 180 volts. Manufacturers rate T8s to light at 180 volts and above, and rate T12s to light at 170 volts and above. Rural and remote areas will typically receive voltage sags to as low as 160 – 165 volts. Neither T12 nor T8 lamps are suitable under such conditions.

disprove the manufacturer claims. Some in the industry suspect that manufacturer claims may be spurious, as it appears surprising that both T8 and T12 are listed with the same level of lumen output and lumen depreciation.

If the consumer perceptions are found to be false, then consumer (and distributor) education programs and promotion must be launched to correct the misperception, at the same time improving awareness of energy efficiency benefits.

If the available T8 lamps are found to have inferior quality, then the industry and energy efficiency advocates should assess what is required to bring local production up to international quality standards, prior to launching the promotion program.

5.3 Energy Efficient FTL Ballasts

A ballast is the control device necessary to light fluorescent lamps. This analysis focuses on ballasts designed for 40-watt (T12) and 36-watt (T8) FTLs, which represent by far the largest ballast market in India. Standard ballasts are the electromagnetic type, manufactured out of either aluminum or copper. There are two energy efficient ballast types, the energy-efficient electromagnetic ballast and the electronic ballast. Both are available in India, though they have a negligible share of the total ballast market. They are each suitable substitutes for either aluminum or copper standard ballasts.

Market Characteristics

All FTL users are also ballast users. In India, essentially all FTL fixtures are designed to use a single ballast to drive each lamp; the distribution of ballasts is the same as the distribution of FTL lamps. Table 5.4 summarizes the market distribution, based upon the preceding analysis of the FTL stock and energy consumption accounting, and also indicates market characteristics that are described further below.

Table 5.4 Ballast Market Characteristics

Consumer Segment	*Market Share*	*Current Product Choice*	*Reasons for Purchase Choice*	*Where Products are Purchased*
Residential	40 %	90% std, aluminum 10% std, copper	Low-cost, availability	Retail shops
Commercial: Small-Scale	40 %	90% std, aluminum 10% std, copper	Low-cost, availability	Retail shops
Commercial: Large-Scale		Primarily std, copper Some EE EM	Long life, high quality	Direct from manufacturers
Industrial: Small-Scale	14 %	Primarily std, aluminum	Low-cost, availability	Retail shops
Industrial: Mid-to-Large-Scale		Perhaps >50% EE EM or electronic Others std, copper	High power factor, long life	Direct from manufacturers
Institutional	6 %	Primarily std, aluminum	Lowest cost	Direct from manufacturers

The manufacture of ballasts is reserved by the Government of India for the small-scale (unorganized) sector. This sector accounts for 90 to 95 percent of the ballast market. Manufacturers of branded products share the remainder, although they also participate principally by outsourcing their technology and quality control systems to small-scale units. Hence, almost all consumers, from all sectors, buy ballasts that are manufactured by very small firms, many of them operating only temporarily, as the manufacturing technology is simple and does not require capital-intensive machinery. No reliable data are available on total ballast sales or the market distribution, because ballasts are the product of the non-reporting sector. Market characteristics are estimates or judgments provided by organized sector manufacturers and distributors.

Market Distribution

The distribution of ballasts, as for FTL lamps, is dominated by the residential and commercial sectors. Each is estimated to have roughly a 40 percent market share. However, the different ballast types are not distributed evenly among the consumer segments in relation to the overall market. Generally, the less-sophisticated consumers in the residential and small-scale sectors have the predominant share of aluminum standard ballasts, which tend to have lower quality. Consumers who have a more sophisticated understanding of ballast characteristics are more likely to select copper-based ballasts, or either of the more energy-efficient types: electronic or EE electromagnetic (EE EM) models. The following characterization is based upon findings of a 2000 study prepared by the International Institute for Energy Conservation and the International Copper Association:[17]

- *Overall distribution of ballasts by type:*
    - 74 percent aluminum electromagnetic, standard
    - 20 percent copper electromagnetic, standard
    - 4 percent EE EM
    - 2 percent electronic
    -
- *Residential sector.* Aluminum, standard ballasts are estimated to account for 90 percent of the residential market, the remainder being copper, standard ballasts.

- *Commercial sector.* Aluminum, standard ballasts also represent a significant portion of this market segment. However, considering the large overall market share represented by the commercial sector, and the 20 percent overall share of copper ballasts, it may be inferred that copper standard ballasts have at least 50 percent of the market in this sector.

- *Industrial sector.* Copper, standard ballasts are estimated to have 35 percent of this market segment, concentrated in the larger companies. The industrial sector

[17] Source : India - Ballast April Review , by IIEC .

accounts also for most electronic ballast sales and the great majority of EE EM ballast sales.

- *Institutional and other sector.* This market is dominated by low-cost, aluminum standard ballasts.

Consumer Purchasing Patterns

Purchasing patterns suggest three groups: (1) residential and the small-scale segments of the commercial and industrial sectors, (2) medium-to-large-scale segments of the commercial and industrial sectors, and (3) institutional sector. Their respective purchasing patterns are described below.

Residential and Small-Scale Commercial and Industrial Segments

Consumers buy from retail shops, though generally with no choice involved. Initially, the ballast is sold as a package with the FTL fixture. When replacing failed ballasts, the consumer will generally buy what the retailer has available or wants to sell.

The only selection criteria of interest to these consumers are generally the cost and life of the ballast. Generally, they are not aware of power losses associated with the ballast, so energy efficiency considerations are moot. They assume that power consumption is wholly attributed to the lamp, for example no more than 40 watts for the T12, and are unaware of the additional 15- to 20-watt consumption of the standard ballast. The poor power factor associated with low-quality standard ballasts also does not concern them. However, there is evidence that the more discerning, upper income residential consumers are showing a preference for slim ballasts, which are higher quality.

Medium- to Large-Scale Commercial and Industrial Segments

This group has a more sophisticated appreciation for the performance features of ballasts. They prefer to purchase the higher quality ballast types, though for different reasons, as follows:

- *Commercial.* Some of the larger commercial consumers are aware of the power consumption of ballasts, and have begun to purchase high efficiency models. Quality considerations in ballast selection are more generally a high priority, with the emphasis on ballast life.

- *Industrial.* Many large industrial consumers are sensitive to the power factor considerations, as well as the lifetime and to a lesser extent the power consumption features. Particularly the large industrial consumers are quality-conscious. They purchase ballasts from the organized sector or small manufacturers with a reputation for quality. Some industrial consumers have standardized their purchasing for electronic ballasts.

Institutional Sector

Institutional consumers purchase ballasts by tender and select from among bids on the basis of lowest cost of supply without considering future operating costs. For this reason, it is expected that the great majority of ballasts in this sector are the aluminum, standard type.

Steps Required to Overcome Market Barriers

The slight penetration of EE EM and electronic ballasts, primarily in the large-scale industrial sector, may be attributed primarily to their high power factor benefit as well as general quality considerations such as long life. Other discerning consumers are interested most in quality and what that brings. However, few consumers are aware of the power losses associated with ballasts nor the energy efficiency benefits of the higher quality, energy-efficient ballast options.

Awareness building must be a vital component of a program to stimulate market penetration of EE ballasts, addressing the long-term costs of inferior quality standard ballasts as well as the multiple benefits offered by EE EM and electronic ballasts. Effective consumer education may begin to move the market in spite of the large price premium associated with these options, as discerning consumers are willing to pay for quality when performance benefits are perceived to be reliable.

The largest share of the ballast market is associated with consumers in all sectors who buy the lowest cost product available. However, it is unknown to what extent this implicit behavior is due to lack of choice in contrast to making a conscious selection among low and high quality products available at their point of purchase. Many distributors or retailers may choose to stock only the low-cost, inferior quality product, and consumer purchasing hence follows. This issue needs to be assessed through further market research, as it influences the extent to which awareness programs may need to address the ballast supply chain.

Even in the large-scale industrial market, an awareness-building program should address lingering concerns among some consumers about the reliability of electronic ballasts. As in American and other markets, early models of electronic ballasts, when first introduced by the leading manufacturers, suffered serious quality problems. This created an impression that the technology was not yet mature, which lingers among some consumers despite correction of the early problems by the manufacturers.

Finally, efforts to stimulate market penetration of the EE products must address economic considerations once the awareness and market chain barriers have been overcome. Good quality standard ballasts cost two to three times the price of poor quality ones. EE EM ballasts command a further premium of 30 – 100 percent, and electronic ballasts cost about 65 percent more than the EE EM ballasts. The significant premiums for energy efficiency in ballasts are likely to deter consumers when they have a choice, even once aware of the operating cost benefits. Thus rebates, purchase price buy-down, installment payment, or other programs aimed to reduce the economic barrier are likely to be necessary to transform the ballast market.

5.4 T5 Fluorescent Lamps with Electronic Ballasts

This product has only recently been introduced to the Indian market. It is also new to many other markets, including the US. The market characteristics are similar to those reported in Section 5.2 for T8 lamps, in that this product is being positioned principally as a replacement for existing single-tube FTL lamps.

The T5 lamp package includes integral electronic ballast in the extension to the tube that is required for it to fit in a standard FTL fixture. The resulting unit offers many advantages over the standard FTL, including the following:

- *Higher light output.* The T5 has greater efficacy than either T12 or T8 lamps, and the lamp size is positioned to provide higher lumen output than the standard lamp, which is evident to consumers in demonstrations.

- *Significant energy savings.* By combining the energy savings of both the high efficiency lamp and ballast, this unit reduces energy use by 50 percent.

- *Less lumen depreciation.* The T5 is superior both to the existing FTL models as well as to HID lamps.

- *High power factor, reduced flicker.* These benefits are due to the electronic ballast.

- *Greater service life.* Suppliers claim that the unit's lifetime is about 10,000 hours, but it is not clear whether this is true under typical Indian operating conditions. The lamps have not been available in India long enough to have consumer experience with this. If true, the T5 package would have about three times the service life of typical FTL lamps, which would help to offset its high cost. The electronic ballast should help to extend the life of the lamp.

The advantages of the T5 unit address each of the market barriers listed for the T8 lamp, as presented in Section 5.2. The T5 is also much easier to differentiate visually from standard FTL lamps than are T8 lamps, due to its much slimmer appearance at less than half the diameter of T12 lamps. All told, the T5 lamp package is positioned as a high quality product alternative to the standard FTL lamp, delivering energy savings as well.

The chief market barrier for the T5, apart from limited consumer awareness, is its high price. It is currently offered at about Rp 600-700, whereas standard FTL lamps cost only about Rp 40. Marketers are addressing this issue by offering installment payment programs, where the payment levels are claimed to approximate the value of energy savings.

Many consumers may be expected to be intrigued sufficiently to try the T5 lamp, as it promises many excellent features and represents a technological advance that appeals to many market leaders. While the price may be expected to fall as the market grows, ultimately the market penetration potential may depend largely upon whether the product can reliably deliver on the claims for long service life. Without the extended lifetime, very few consumers will find that energy savings will pay for the T5's price premium, even if the price dropped by 50 percent. And consumers are unlikely to be repeat purchasers if they find that T5s do not last significantly longer than the inexpensive T12s.

5.5 Energy-Efficient Refrigerators

Refrigerator sales are confined to the residential and the small-scale commercial sector in the retail food and food service segments. Whereas the 1990 ACEEE study found that Indian refrigerators were very energy inefficient, relatively high efficiency refrigerators have become available from domestic manufacturers and the average efficiency level of new models on the market has improved. Nevertheless, high efficiency refrigerators are estimated to have no more than a 5 percent share of the market.

Market Characteristics

A 1998 market research report indicated that the refrigerator market is uniform among the major urban centers of the country, and that national brands are the most popular among consumers. [18] The top three brands shared 65 percent of the market at that time. Table 5.5 summarizes the market characteristics and consumer preferences that are presented below:

- *Market segmentation.* NCAER provides demographic data on refrigerator ownership, leading the study team to the following estimates:
  - *Rural residential market.* Rural households account for 24 percent of residential refrigerator purchases.
  - *Urban residential market.* The remaining 76 percent of residential refrigerator purchases are by urban households. Nearly 3 percent of the urban refrigerator owners own more than one refrigerator.
  - *Commercial market.* No data was available for the extent of refrigerator sales or ownership in the commercial sector. The share of sales was assumed to be 5 percent.

- *Refrigerator capacity distribution:*
  - *3% Less than 165 liters (90 and 100 liters)*
  - *71% 165 liters*
  - *19% Greater than 165 liters (primarily 220 and 310 liters)*

[18] This study was performed jointly by Sofres-Mode (a market research firm) and IRG under the USAID/ EMCAT-DSM Phase 2 project. The study sample included consumers in Delhi, Mumbai, Chennai, Calcutta, Bangalore, and Ahmedabad. It was conducted during the period December 1997 – January 1998.

In the rural market, nearly all refrigerators are expected to be the 165-liter size, while the distribution is expected to be more varied among urban households. The commercial segment tends to purchase refrigerators that are larger size than 165 liters.

Table 5.5 Refrigerator Market Characteristics

Consumer Segment	*Market Share*	*Current Product Choice*	*Reasons for Purchase Choice*	*Where Products are Purchased*
Residential: Urban	72 %	165 liters and larger	Primarily brand, also price and capacity	Retail shops
Residential: Rural	23 %	165 liters primarily	Price and brand conscious	Retail shops
Commercial	5 %	Greater than 165 liters	Unknown	Retail shops

The EMCAT study also assessed consumer preferences in selecting the type of refrigerator to purchase. In a free-response question, the largest group of respondents (26 percent) cited brand as the most important factor in their selection, while other important factors included refrigerator capacity (8 percent), compressor type (8 percent), and price (8 percent). Energy consumption level was cited by only 3 percent of respondents.

A second type of question in the EMCAT study asked respondents to rate a list of factors influencing their selection on a 5-point scale from very important to very unimportant. The following indicates the percentage of respondents who rated the indicated factor as very important:

- 92% compressor
- 90% cooling ability
- 89% reliability/durability
- 87% power efficiency
- 83% BIS-issued ISI mark
- 82% brand name
- 80% capacity
- 79% frost-free feature
- 61% price
- 59% physical size

The degree to which the factor ratings are statistically different from one another is unknown. However, the results of this prompted question suggest that consumers consider a large number of refrigerator attributes and do not differentiate their importance to a large degree. Although the sample is not characterized, the relatively high rating given to a frost-free feature (presumed to be available only for large units) and the low rating given to price, suggest that the sample may represent relatively high income consumers disproportionately. Regardless, for this sample the combination of relatively equal importance attached to multiple dissimilar attributes, and low importance attributed to price, suggests that it may be difficult to establish prospective energy savings as a feature that drives refrigerator selection more than other factors.

Steps Required to Overcome Market Barriers

The survey findings suggest that the price premium associated with EE refrigerators may not be an important deterrent that requires market intervention, but that awareness is an important issue needing attention. This may be addressed through a combination of promotion and identification, such as using energy efficiency rating levels. Due to the multiplicity of product features that are important to buyers, energy efficiency would need to be bundled with other features that they value.

Future market research should also be conducted to differentiate the preference characteristics for rural and urban lower and lower-middle income consumers, who collectively represent a significant and perhaps dominant share of the refrigerator market. Based upon evidence of these groups' buying habits for lighting products, they may be expected to be more narrowly price conscious and focused on the lower-end, 165-liter refrigerator models that offer few features. This market segment may be more amenable than higher income households to targeted market intervention aimed to boost EE refrigerator penetration, potentially requiring also financial incentives.

5.6 Energy-Efficient Room Air Conditioners

In contrast to the refrigerator market, the market for room AC units has a strongly local character, due to the significant share of production by the unorganized sector, at nearly 50 percent. This sector produces assembled units.

The efficiency level of room AC units has improved significantly in India over the last 10 years. At that time, according to the 1991 ACEEE report, the BIS voluntary standard for energy efficiency ratio (EER) was in the range of 6.6 to 7.0, while many units on the market had EERs as low as 5.0. In 1996, the EMCAT study reported that standard units on the Indian market had EERs in the range of 6.0 to 8.0, and that units were available on the market with an EER of 10.0 although their sales were very low. Today the EER range of branded units on the market is incrementally higher, typically in the range of 8.0 to 9.0. Still, high efficiency units are available with EERs of 10.0, though none are available at the higher levels (e.g., exceeding 13.0) found in many other countries. The current efficiency range of non-branded units is not known.

Market Characteristics

Air conditioner ownership in the residential sector is still limited to about 1 percent of urban households and essentially nil among rural households.[19] An industry report indicates that eight cities account for 65 percent of household AC demand.[20]

Room AC units are also found in the institutional and industrial sectors, though in relatively negligible numbers. The commercial sector represents the other significant market, estimated to be approximately equivalent in size to the urban residential market.

[19] EMCAT (the same Sofres-Mode/IRG study as cited previously for the refrigerator market).
[20] Source: Industry report: Refrigeration and Air Conditioning, Business Newsweek, October 2000.

The AC market is highly seasonal, with the bulk of purchases occurring during the summer season. Availability is sometimes a limiting factor in consumer choice among models when the purchase is made during the peak season.

Table 5.6 summarizes the characteristics of the AC market. It is focused on a narrow range of products in terms of unit capacity. The typical room AC unit is rated at 1.5 tons of refrigeration (TR), and the typical branded unit has an EER in the range of 8.0 to 9.0. Consumers shop with a variety of features in mind, and generally do not buy units for their energy efficiency but for an acceptable package of desired attributes. Considering that only the most affluent households (the top 1 percent) own AC units, they may not be expected to be very sensitive to either price or operating costs.

Table 5.6 Room Air Conditioning Unit Market Characteristics

Consumer Segment	*Market Share*	*Current Product Choice*	*Reasons for Purchase Choice*	*Where Products are Purchased*
Residential: High Income	50 %	25% 1 TR or less 60% 1.5 TR	Multiple features, not price or EER	Retail shops
Commercial	50 %	15% 1.5 – 2.0 TR	Unknown	Retail shops

Market research findings are based upon the same EMCAT survey as cited previously for refrigerators. Consumers reported consistently that their most important selection criterion was cooling capacity (29 percent), while power efficiency (6 percent) and price were less important. Brand identification is less important than for refrigerators. While buyers of branded products indicated that brand is important, nearly 50 percent of consumers buy unbranded products. When presented with a list of factors to rate by importance in their purchase decision, responses emphasized cooling ability and reliability.

Consumers do not identify power efficiency, or EER, as an important consideration in their purchase decision. This may be because manufacturers have not promoted this feature or its value to the consumer. Or, it may be that consumers who are wealthy enough to purchase and operate AC units are so focused on ensuring sufficient cooling capacity, quietness, variability of settings, and other features that EER and operating cost seem to be marginal considerations. Further market research is necessary to explore their true preferences.

Steps Required to Overcome Market Barriers

While the majority of household AC buyers may appear to be less responsive to unit efficiency than to other product features, this may be due to insufficient or misdirected promotion of the meaning of EER. Likely, few consumers have a clear idea of the cost of AC use. They may respond to clear messages about the value of EE units in terms of electricity bill savings per cooling season, or to the concept of obtaining the same cooling capacity for less power input (or more cooling capacity for the same input as a standard unit). Further consumer research could resolve these questions before launching an extensive promotion campaign or appliance labeling program.

Another market transformation approach, aimed to overcome the possible case of persistent consumer indifference to AC operating cost, would be to make existing EER standards mandatory.

No market information was available concerning commercial sector buyer preferences. This sector may have different buying patterns and market intervention needs, and should be assessed in future consumer research.

5.7 Energy-Efficient Ceiling Fans

Most households own ceiling fans, and they are also common in nonresidential buildings. No survey research has been performed recently concerning fan ownership, consumer preferences, or market distribution. The fans are supplied principally by the small-scale sector. Consumer demand in the largest markets is driven by price, with no awareness or apparent availability of high efficiency models. Features available in higher priced models include variable speed control (continuous or in steps), color and style variations.

Although the per-unit EE potential in ceiling fans is relatively low, their pervasive ownership implies large EE potential in the country. However, small EE motors are not produced in India, and hence the key component is not available to produce EE fans domestically. This is clearly the first barrier to EE potential. Yet the EE price premium may also be expected to be a major barrier, competing with other valued features such as speed variability and styling.[21]

Significant efforts would be required to overcome the market barriers that prevent production and marketing of EE ceiling fans. They may include direct government assistance to develop manufacturing capability of the requisite small EE motors, financial incentives to consumers or manufacturers (fan or motor manufacturers), a consumer marketing campaign, and labeling or efficiency standards. Further survey work and analysis was not conducted on this product in view of the barriers and the availability of more promising potential in other EE products.

5.8 Energy-Efficient Motors

Electric motors are pervasive in the economy and the dominant source of electricity consumption in most consumer sectors. The distribution of motors among consumers shows that the industrial sector has the dominant market share (see Table 5.6), while the residential sector has the greatest technical EE potential. Significantly, however, in many segments it is not the final consumers who are materially responsible for the selection of standard versus EE motors, but another set of stakeholders who have their own interests

[21] Economic and market potential for EE ceiling fans are discussed in the companion report, *Market Potential for Branded Energy Efficient Products.*

that are quite divorced from energy cost considerations. This market background is more complex than that of the preceding products.

Market Characteristics

In characterizing the motor market, it is best to describe the end users, in terms of the consumer sectors considered for other products, their buying habits, and then to consider the set of stakeholders who may have the most direct influence on the selection of motor types. Table 5.7 summarizes the electric motor market in terms of the four principal consumer sectors. Motor applications for each sector are described below:

- *Residential consumers* use motors in domestic appliances, including electric ceiling and table fans, refrigerators, washing machines, air coolers, air conditioners, kitchen appliances, water pumps, and the like. In these appliances, the motors account for essentially all of the electricity consumption, though each motor is essentially invisible to the consumer, being housed in the appliance itself. In purchasing the appliance, the consumer makes his selection decision based upon the features of the appliance, generally with no information about (or concern for) the characteristics of the motor inside. The motor has been selected by the appliance manufacturer (i.e., original equipment manufacturer or OEM).

- *Commercial consumers* use motors in fans, air conditioners and HVAC systems, refrigerators, pumps, elevators, etc. As for the appliances used by residential consumers, OEMs are responsible for motor selection in the majority of commercial motor applications. Only in large buildings do the commercial business managers have responsibility for motor selection and repair, principally in their HVAC systems, though this also may be done indirectly through the consumer's agents (e.g., design engineers, maintenance contractor, motor distributor, etc.).

- *Industrial consumers* use motors in by far the most diverse array of applications, including some of the appliances used in other sectors but principally in industrial equipment: process equipment (grinders, separators, mixers, etc.), machine tools, pumps, fans, blowers, compressors, material handling equipment (conveyors, hoists, cranes, etc.), and other applications. Whereas residential and all but the largest commercial consumers use predominantly small motors, the industrial sector uses a broad array of sizes and specialized motor types. Many industrial machines are also assembled and supplied by industrial OEMs, but industrial end users are directly responsible for specifying and maintaining a large portion of their motors.

- *Institutional consumers* are diverse, including government bodies that use motors in applications that are similar to commercial consumers, and entities that use motors in applications that are more similar to industry, such as water pumping stations, wastewater treatment, and port authorities. As in the case of the other product categories described previously, institutional consumers have procurement practices that differentiate them from other consumers.

Table 5.7 Motor Market Characteristics

Consumer Segment	*Market Share*[22]	*Current Product Choice*	*Reasons for Purchase Choice*	*Where Products are Purchased*	*Motor Selection Responsibility*
Residential	32 %	Std motors, 1-phase, < 5 kW	Appliance features /OEM selection	Retail shops	OEMs only
Commercial: Small/Medium	12 %	Std motors, 1-phase, < 5 kW	Equipment features, least cost	Distributors, traders, used equip markets	OEMs, distributors
Commercial: Large		Std motors, 1- & 3-phase, up to 15 kW	Designer spec/OEM, least cost for repair or replacement	OEMs; motor manufacturers, traders; motor repair shops	OEMs, eng'g consultants, end user, repair shops
Industrial: Small	12 %	Std motors, 1-phase, < 5 kW	Least cost/OEM selection	Distributors, traders, used equip markets	OEMs, distributors, end user
Industrial: Medium/Large	40 %	Std motors, 1- & 3-phase, all sizes	Designer spec/OEM, process req'ts, reliability, least cost replacement	OEMs; motor manufacturers, traders; motor repair shops	OEMs, eng'g consultants, end user, repair shops
Institutional	4 %	Std motors, 1- & 3-phase, all sizes	Designer spec/OEM, least cost replacement	Distributors, traders, manufacturers, OEMs	OEMs, contractors, end user, bidders

This characterization emphasizes how remote many end users are from the selection of motors they use and for which they are responsible for operating costs. There are four principal categories of stakeholders who are responsible for motor selection across all the consumer sectors: OEMs, market intermediaries, consulting engineers and contractors, and end users. They are described further below and illustrated in Figure 5.1.

[22] Market share is expressed in terms of the share total motor energy consumption represented by the consumer sector, rather than in terms of numbers of motors or installed capacity.

Original Equipment Manufacturers (OEMs)

OEMs probably account for the largest share of motors selected. In the US, OEMs account for the purchase of more than 50 percent of integral horsepower, 3-phase induction motors, and essentially all single phase motors. OEMs compete in highly price sensitive markets and are typically reluctant to incorporate components that would increase final product costs. They have no stake in the energy consumption of their end product. OEMs do not buy EE motors because they carry a price premium that would translate to a price increase in their final product, which is perceived as more likely to reduce sales than to add sufficient value to maintain or increase sales.

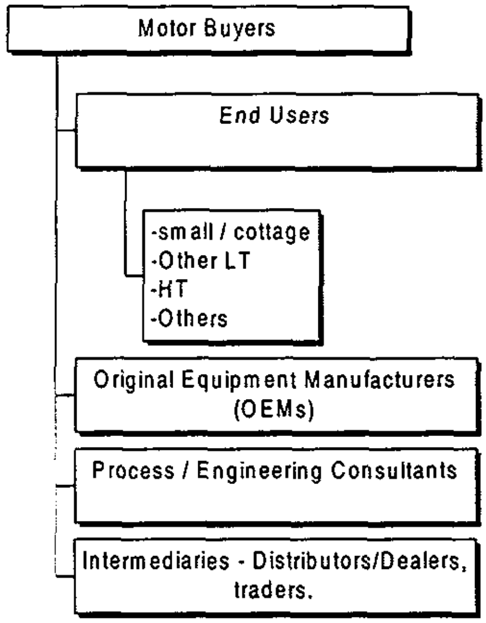
Small OEMs generally buy their motors from a distributor, while large OEMs buy in bulk direct from the manufacturer.

Distributors, Dealers, Traders, And Other Market Intermediaries

Market intermediaries probably account for the next largest share in India. They account for one-third of integral horsepower, 3-phase induction motors in the US. This category is a fractured group including large, organized dealers affiliated with brand-identified manufacturers, sellers of motors produced by local unorganized-sector manufacturers, traders of various branded products, and small motor repair shops that will recommend or sell replacement motors to clients as required.

This part of the market chain is an important contact point with the consumers. The dealers do not stock EE motors because consumers rarely request them. They are considered a very "slow-moving" item that takes up valuable shelf space, reducing revenue turnover.

Figure 0.1 Profile of Motor Buyers



Consulting Engineers And Other Contractors

Consultants and contractors specify the motor requirements associated with process and building equipment in the industrial, large commercial and institutional sectors. They rarely specify EE motors, as they tend to focus on the performance requirements of the system that the motor works in, rather than focusing on the operating cost aspects of the motor itself.

Some consultants point out that their efforts to specify EE motors have been stalled by the motor manufacturers, who require longer delivery times for EE motors. Manufacturers claim that the increase in delivery time is minor (a few weeks), and should not be a problem for new projects (where consultants are generally involved), which typically have large lead times. However, excessive delivery times compared to standard motors are certainly a deterrent to EE motor specification when replacing motors.

End Users

End users represent the only member of these stakeholders with a clear interest in selecting motors to optimize across all performance criteria, including energy costs. In the US, end users account for only 13 percent of direct purchases from manufacturers, though these purchases are principally for very large motors required by large industrial plants. End users often specify replacement motors, ordering through market intermediaries rather than directly from manufacturers. However, their selection is often limited by what is available in stock from intermediaries, particularly in the typical circumstances that require motor replacement as quickly as possible.

Following is a list of reasons given by end users who specify standard rather than EE motors:

- Lack of awareness of the payback benefits of EE motors
- Lack of awareness of source of EE motors
- Lack of timely availability of EE motors and after sales service support
- Skepticism about claimed EE motor paybacks
- Perception that EE benefits may be lost after rewind
- Reluctance to invest more money in EE motors
- Financial constraint to invest in EE motors
- Inability to select products on the basis of life cycle costing rather than lowest first cost in the case of government or institutional sector buyers

End users vary considerably in their level of sophistication and understanding of the implications of their motor selection decisions. Small-scale users buy from retailers or direct from small, unorganized sector manufacturers. Motor efficiencies are rarely considered in these transactions. Large companies arrange bulk purchases directly with manufacturers. Motor efficiency may be considered, but would rarely be a deciding factor in the selection. Mid-sized companies' practices fall in between. They generally buy from market intermediaries. Institutional consumers may or may not be aware of energy efficiency considerations. They are constrained to buy on the basis of lowest first cost, but may be able to include a minimum efficiency level in their motor specifications.

Steps Required to Overcome Market Barriers

Each of the buyer categories—OEMs, market intermediaries, consultants/contractors, and end users—requires a separate approach to influence EE motor specification and stimulate market penetration.

The purchase behavior of OEMs is very difficult to influence because their market is very price competitive, their products compete on performance features where operating cost generally ranks quite low, and because they are relatively removed from the direct link to end users compared to other categories. However, a few market transformation programs have been successful at inducing OEMs to use EE motors, generally by stimulating demand broadly among end users and distributors through an aggressive blend of promotion, financial assistance, and collaboration with trade allies in the supply chain.

Distributors and other market intermediaries need to be involved early in the design of market transformation programs, particularly as the enthusiasm of their sales forces is critical to success. Furthermore, they understand the market well and are vital to the sustainability of initiatives, as they will remain in the market long after "programs" have disappeared.

Consultants and contractors require awareness-building programs to appreciate the operating cost implications of their motor specifications. Ultimately, they will align their practices closely with the demands of end users. Once strong demand for EE motors is established among end users, and good communication lines are established with designers, then this group also will specify EE motors.

End users generally require a combination of awareness building promotional/education programs, technical assistance, and financial assistance. Financial assistance is important in providing incentives for end users to choose EE motors over standard motors, though incentive levels can be reduced over time once the market has been effectively stimulated. Financial assistance is particularly important for programs seeking to influence end users to replace failed motors with EE motors rather than rewinding them.

The value of technical assistance cannot be overemphasized, and is relevant to distributors/market intermediaries and consultants as well as end users. Technical assistance may include publications, analytical tools for comparing motor alternatives, and educational seminars. The latter are important to dispel perceptions of poor reliability or unsubstantiated manufacturer claims for EE motors that may persist even among vendors and distributors.

Section 6 References

1. MMEE presentation copy, 2000
2. EMCAT reports. Efficient Electric End Use Devices: The Indian Market
3. ACEEE: Opportunities for Improving End Use Electricity Efficiency in India 1991.
4. ADB Energy Efficiency Support Project Consolidated Report (TA 2193)
5. IIEC, CFC Energy Efficiency Program - India Workshop Proceedings, 1999.
6. Compendium of Environment Statistics 1999, CSO, Min. of Statistics & Program Implementation, GOI.
7. Status Report for Selected Domestic Appliances (Vol I to VI), Kirloskar Consultants, 1997.
8. Southern California Edison, Low Income Relamping, The Results Center, IRT Environment, Inc., 1992.
9. Burlington Electric Department: Smartlight, The Results Center, IRT Environment, Inc, 1992
10. Lessons Learned: A review of Utility experience with conservation and Load Management for Commercial and Industrial Customers, NYSERDA, 1990.
11. ELCOMA Documents (directory, representation to Ministry of Power), 1999
12. ISLE (Indian Society of Lighting Engineers) Directory 1999.
13. IEEMA Production Statement, 1999-2000; Motor Report - Vision 2000.
14. Draft IEEMA standard 2000, IS12615, and IS8789 for Energy Efficient Induction Motors (3 Phase Sq cage).
15. Indian Market - Electric Motors, IEEMA journal, September 1999
16. Energy Efficient Motors; Presentation by Crompton Greaves Ltd.
17. Energy Efficient Motors; Presentation by Bharat Bijlee ltd. 2000.
18. ISHRAE directory

19. Manual on Energy Efficient Motor, India -US Motor Challenge Programme 1999 under India - USA Bilateral Cooperation on Energy Efficiency, Prepared by Mahratta Chamber of Commerce, Pune, Sponsored by EMC, Min of Power, GOI, New Delhi.

20. National Sample Survey Organization report on Households,

21. National Sample Survey Organization report on energy usage, electricity usage.

22. Monthly Abstract of Statistics CSO, GOI, July 2000, Released October 2000

23. Annual Abstract of Statistics, CSO, GOI, 1999.

24. Energy Statistics - 1998 - 99; CSO, GOI.

25. Indian Market Demographic Report, NCAER Publications, 1998.

26. 15 th Electric Power Survey of India, July 1995, CEA, GOI.

27. Public Electricity Supply, General Review: 1996-97; CEA, GOI.

28. TERI: TEDDY 2000.

29. Climate Change in Asia / Brazil, Asia energy Institute, AEI Thailand / TERI, 1994.

30. TERI / UNEP: Environmental Considerations and Options in Managing India's Long Term Energy Strategy, 1995.

31. ECO - Refrigeration, Conference on Hydrocarbon Fluids in Commercial / Domestic Refrigeration, 1997.

32. CII proceedings Energy Efficiency - Concepts, Strategies, Business opportunities.

33. CMIE Report on Industrial Performance. June 2000

34. CMIE report on Energy 1999.

35. Economic Survey 2000, GOI.

36. ACEEE preview of publications on: Chinese Green Lights Program.

37. ACEEE preview of publications on: Chinese Motors Market.

38. ACEEE preview of publications on: End Use Efficiency in Brazil, EE lighting in Brazil .

39. ACEEE preview of summer study on EE in Buildings - Electric Utility Conservation Programs; review of lessons taught by decade of program experience, 1990.

40. Personal Communications with: Secretary IEEMA. Bombay.

41. Personal Communications with Secretary ELCOMA, New Delhi.

42. Personal Communications with Secretary All India Electric Motor Manufacturers Association, Bombay

43. Personal Communications with Manufacturers: - Vice President, GE Lighting.

44. Personal Communications with Manufacturers: - Vice President, OSRAM India Ltd, New Delhi (Gurgaon).

45. Personal Communications with Manufacturers - Head of Marketing, Surya Roshni Ltd, New Delhi.

46. Personal Communications with Manufacturers: - G M (Commercial) Surya Roshni Ltd, New Delhi.

47. Personal Communications with Manufacturers: - AM, Crompton Greaves, Lighting Business, Bombay.

48. Personal Communications with Manufacturers: - Regional Manager, Philips Ltd, Bombay.

49. Personal Communications with Manufacturers: G M (Technology) Crompton Greaves, Motors, Bombay.

50. Personal Communications with Manufacturers: - Vice President, Bharat Bijlee Ltd, Bombay.

51. Personal Communications with Manufacturers: - A.Vice President, Kirloskar Electric Ltd (Motors) New Delhi.

52. Personal Communications with Manufacturers: - DGM (AC Projects division.) Blue Star Limited, Bombay.

53. Personal Communications with Manufacturers: - GM (Package AC divn) Blue Star Limited, New Delhi.

54. Personal Communications with Manufacturers: - Country Leader, Trane India Ltd, Liaison office, New Delhi.

55. Personal Communications with Manufacturers: - GM - AC & R, Voltas Ltd.

56. Industry Catalogues / Web Sites of: Lighting Products Manufacturers: Philips, Crompton, Baja, OSRAM, Surya Roshni, Bajaj electricals ltd.

57. Industry Catalogues / Web Sites of: Motors Manufacturers: Crompton Greaves, Bharat Bijlee, Kirloskar, ABB.

58. Industry Catalogues / Web Sites of: -HVAC Equipments: Trane, Voltas, Blue Star, Carrier.